

Endovascular and open surgical repair of abdominal aortic aneurysms: A comparative analysis of western and Chinese studies

Feng Shi¹, Yuchen He², Shiyue Wang², Fuqiang Jia³, Chao Ji⁴, Jian Zhang², Xun Liu⁵ and Yanshuo Han^{6,*}

¹Department of Health Management, Shengjing Hospital of China Medical University, Shenyang 110004, P. R. China

²Department of Vascular Surgery, the First Hospital of China Medical University, and Key Laboratory of pathogenesis, prevention and therapeutics of aortic aneurysm Liaoning Province, Shenyang 110001, P. R. China

³Yingkou Vocational and Technical College, Yingkou 115000, P. R. China

⁴Department of Clinical Epidemiology, Shengjing Hospital of China Medical University, Shenyang 110004, P. R. China

⁵Department of General Surgery, Shengjing Hospital of China Medical University, Shenyang 110004, P. R. China

⁶School of Life Science and Medicine, Dalian University of Technology, Panjin 116024, P. R. China

*Correspondence: yanshuohan@dlut.edu.cn (Yanshuo Han)

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Abdominal aortic aneurysms (AAA) are life-threatening serious conditions that require effective and quick management. Although it is generally acknowledged that patients with AAA obtain the greatest benefit from endovascular repair (EVAR) compared to open surgical repair (OSR), there are few comparisons between the surgical approaches in Western versus Chinese patients. We aimed to perform a meta-analysis of studies in which EVAR was compared with OSR in the management of abdominal aortic aneurysms. We searched the Western literature through PubMed, OVID and Web of Science from 1991 until December 2018 and the Chinese-language literature from 1998 until December 2018. We pooled the results in January 2019 based on standardized inclusion and exclusion criteria and analyzed them using a conventional meta-analysis. Forty-five English papers with 31,074 AAA patients and twenty-one Chinese studies with 1,405 patients were included in this study. Chinese subjects were more likely to undergo endovascular repair than Western subjects (44.5% versus 41.5%, $P = 0.012$). The 30-day post-discharge mortality rate in Western studies was significantly lower for EVAR than for OSR (odds ratio (OR) = 0.481, $P < 0.001$). However, there was no significant reduction in the 30-day mortality rate following EVAR compared to OSR (OR = 0.733, $P = 0.425$) for Chinese patients. In Western patients, the postoperative complication rate of respiratory system and cardiac system was lower in the EVAR group than in the OSR group (OR = 0.270, $P < 0.001$ and OR = 0.411, $P < 0.001$, respectively), nevertheless, for Chinese patients, limb ischaemia was more common (OR = 1.539, $P = 0.049$) in the EVAR group. Whether in Western patients with an eight-year follow-up period or Chinese patients with a maximum four-

year follow-up period, there was no significant difference between the EVAR and OSR groups in the all-cause death rate (hazard ratio (HR) = 1.026, $P = 0.483$ and HR = 1.173, $P = 0.247$, respectively). Chinese patients were more likely to receive EVAR than OSR and the 30-day mortality was significantly lower for EVAR than for OSR in Western patients but not in Chinese patients. Endovascular repair can be applied to Chinese patients with a reasonable safety margin. Further work is needed to explore the causes of these treatment differences.

Keywords

Aortic aneurysm; abdominal; ethnic group; endovascular repair; open surgical repair; meta-analysis

1. Introduction

The abdominal aortic aneurysm (AAA) is one of the most common silent killers in elderly men. Rupture of an abdominal aortic aneurysm is usually fatal. Endovascular repair (EVAR) techniques and especially elective repair have been applied in the treatment of abdominal aortic aneurysms both in Western countries (i.e., Europe and North America) and China (Adriaensen et al., 2002; Lovegrove et al., 2008). Most randomized controlled trials comparing EVAR and open surgical repair (OSR) were conducted in Europe (De Bruin et al., 2010) and North America. In contrast, scant data are available in Chinese populations. As EVAR use expands to new regions as an alternative method to OSR, questions regarding its usage in non-Caucasian patients have been raised.

A meta-analysis by (Adriaensen et al., 2002) examined short-term discrepancies between EVAR and OSR using data which

Table 1. Characteristics of studies comparing endovascular aortic aneurysm repair and open surgical repair in Western patients with elective abdominal aortic aneurysms.

Study	Year of Publication	Study Period	Study Location	Journal of Publication	No. of Institutions	EVAR	OSR	Study Design	Follow-up EVAR	Follow-up OSR	Comments
McNally et al	June, 2010	2004. 7-2007. 7	USA	J. Vasc. Surg.	single-center	173	228	Retro.	...	...	
Jetty et al	March, 2010	2002. 4. 31-2007. 3. 31	Canada	J. Vasc. Surg.	multicenter	888	5573	Retro.	5	5	CIHI-DAD Database \$
Turnbull et al	March, 2010	2002. 2. 25-2003. 4. 14	USA	J. Vasc. Surg.	13 centers	166	243	PNR	5	5	eLPS £
Steinmetz et al	January 8, 2010	1999. 1-2006. 12	France	Eur. J. Vasc. Endovasc. Surg.	single-center	148	134	Retro.	5	5	Include High-risk exclude low-risk
Chisci et al	2009	2005. 1-2007. 12	Italy and Sweden	J. Endovasc. Ther.	2 centers	74	61	Retro.	1.6	2.1	Exclude Fenestrated EVAR
Dick et al	March. 29. 2008	1998. 1-2002. 12	Switzerland	World. J. Surg.	single-center	68	244	Retro.	4.6	4.9	Exclude emergency OSR
Cronenwett et al	December, 2007	2003. 1-2006. 12	USA	J. Vasc. Surg.	9 hospitals	495	667	PNR	1	1	VSGNNE Database †
Faizer et al	June. 2007	1999. 1-2004. 12	USA	J. Vasc. Surg.	single-center	304	558	Retro.	...	...	
Chan et al	March. 2007	1997. 1-2005. 10	UK	Int. J. Clin. Pract.	single-center	157	329	Retro.	...	...	
Aljabri et al	December, 2006	NG	Canada	J. Vasc. Surg.	single-center	43	33	PNR	0.5	0.5	
Sicard et al	August, 2006	NG	USA	J. Vasc. Surg.	5 IDE‡	565	61	Retro.	2.7	2.5	High-risk
Johnson et al	March 15, 2006	2001. 5. 1- 2003. 9. 30	USA	Am. J. Surg.	123 VA hospitals	717	1187	Retro.	1	1	VA-NSQIP Database
Bush et al	January, 2006			J. Am. Coll. Surg.							
Aarts et al	August 2, 2005	1998. 10-2004. 1	Netherlands	Ann. Vasc. Surg.	single-center	99	116	Retro.	1.9	1.9	
Vogel et al	August 1, 2005	1998-2003	USA	Ann. Vasc. Surg.	single-center	92	126	PNR	...	...	Short Form 36 (SF-36)
Soule et al	August, 2005	1998. 9-2002. 7	Canada	J. Vasc. Interv. Radiol	single-center	20	20	RCT	2.4	2.3	
Lifeline Registry	July, 2005	NG	USA	J. Vasc. Surg.	4 IDE ‡	2063	334	Retro.	> 5	> 1	AnCure, AneuRx, Excluder, PowerLink
Hua et al	March, 2005	2000. 1. 1-2003. 10. 31	USA	Am. J. Surg.	14 centers	460	582	Retro.	...	...	NSQIP-PS Database¶
Goueffic et al	2005	1995. 1-2001. 12	France	J. Endovasc. Ther.	single-center	209	289	PNR	1.6	3.3	
Carpenter et al	November, 2004	2000. 7. 18-2003. 3. 31	USA	J. Vasc. Surg.	15 centers	192	66	PNR	1	1	PowerLink
Wang et al	September, 2008								4.1	3.1	
Cao et al	November, 2004	1997. 1-2003. 12	Italy	J. Vasc. Surg.	single-center	534	585	PNR	2.8	2.9	
DREAM (Prinssen)	October, 2004								...	...	Dutch Randomized Endovascular
DREAM (Blankensteijn)	June 9, 2005	2000. 11-2003. 12	Netherlands	N. Engl. J. Med	24 + 4 centers §	171	174	RCT	2	2	Aneurysm Management
DREAM (Bruin)	May 20, 2010								6	6	(DREAM) Trial Group
Garcia-Madrid et al	October, 2004	1997. 3-2000. 8	Spain	Eur. J. Vasc. Endovasc. Surg.	single-center	53	30	Retro.	1.6	2.2	

Table 1. Continued

Study	Year of Publication	Study Period	Study Location	Journal of Publication	No. of Institutions	EVAR	OSR	Study Design	Follow-up EVAR	Follow-up OSR	Comments
Rigberg et al	September, 2004	2001. 1-2002. 12	USA	Arch. Surg.	single-center	61	89	Retro.	...	...	
EVAR trial 1	August, 25, 2004	1999. 9. 1-2003. 12	UK	Lancet.	34 centers	543	539		...	...	The EVAR trial participants
	June 25, 2005							RCT	2.9	2.9	
	May 20, 2010	1999. 9. 1-2004		N. Engl. J. Med	37 centers Φ	626	626		5	5	
Ballard et al	April, 2004	2000. 11-2003. 5	USA	J. Vasc. Surg.	single-center	22	107	PNR	...	...	PCS-12 and MCS-12
Elkouri et al	March, 2004	1999. 12. 1-2001. 12. 1	USA	J. Vasc. Surg.	single-center	94	261	Retro.	> 0.08	> 0.08	
Lee et al	March, 2004	2001. 1. 1-2001. 12. 31	USA	J. Vasc. Surg.	986hospitals	2565	4607	Retro.	...	...	
Zeebregts et al	January, 2004	1998. 4-2003. 1	Netherlands	Brit. J. Surg.	single-center	93	82	PNR	1.6	1.7	Exclude former OSR
Moore et al	July, 2003	1995. 11. 22-1998. 2. 12	USA	J. Vasc. Surg.	multicenter	573	111	PNR	5	5	EGS & Ancure £
Jordan et al	May, 2003	2000. 1. 1-2002. 6. 12	USA	Ann. Surg.	single-center	130	87	Retro.	...	...	High-Risk
Criado et al	April, 2003	1999. 3. 24-2000. 9. 19	USA	J. Vasc. Surg.	17 centers	240	126	PNR	1.1	0.9	Talent LPS
Matsumura et al	February, 2003	1998. 12-2000. 1	USA	J. Vasc. Surg.	19 centers	235	99	PNR	5	5	Excluder
Peterson et al	May, 2007										
Hansman et al	January, 2003	1999. 11 - 2002. 1	USA	Am. J. Surg.	single-center	50	50	Retro.	...	...	
Arko et al	2003	1996. 10-2000. 7	USA	J. Endovasc. Ther.	single-center	153	141	Retro.	...	...	
Ligush et al	September, 2002	1999. 12-2001. 6	USA	J. Vasc. Surg.	single-center	33	66	Retro.	...	...	
Teufelsbauer et al	July, 29, 2002	1995. 1-2000. 12	Austria	Circulation.	single-center	206	248	Retro.	2.5	2.5	
Cuypers et al	April, 15, 2001	1996. 9-1999. 10	Netherlands	Brit. J. Surg.	2 centers	57	19	RCT	...	...	
Brewster et al	June, 1998	1994. 1-1997. 5	USA	J. Vasc. Surg.	single-center	28	28	Retro.	...	...	

Note: EVAR: elective endovascular repair; OSR: elective open surgical repair; Retro: retrospective data collection; PNR: prospective non-randomized trial; RCT: randomized controlled trial;

\$: Database described as Canadian Institute for Health Information Discharge Abstract Database in Ontario

£: Stents system described as Talent enhanced Low Profile System

†: Database described as Vascular Study Group of Northern New England, in this paper we excluded the following data: Carotid endarterectomy, lower extremity bypass and rupture AAA open surgical repair.

||: Database described as Veterans Health Administration's National Surgical Quality Improvement Program.

‡: The following endografts were used: Guidant-AnCure, Medtronic-AneuRx, Gore-Excluder and Endologix-PowerLink.

¶: Database described as National Surgical Quality Improvement Program Private Sector.

§: The composition of the DREAM Trial Group includes 24 centers in the Netherlands and 4 centers in Belgium.

Φ: Until August 2004, the EVAR trial consisted of 37 clinical centers which included 34 centers that were reported in 2004 and 2005 and an additional 3 centers that contributed 170 patients.

Φ: Two scoring systems were considered: PCS, Physical Component Summary score and MCS, Mental Component Summary score.

£: Stents system includes an EGS component at 18 sites and an Ancure component at 21 sites.

Table 2. Detailed Overview over the Characteristics of Studies from 21 Chinese Cohorts.

Study	Month and Year of Publication	Study Period	Total	Actual	EVAR	OSR	Follow-up EVAR	Follow-up OSR	Database
LI Honghao et al	September, 2010	2001. 1. 1-2008. 12. 31	33	27	11	16	...	...	Sun Yat-sen Memorial Hospital
LI Xinxu et al	June, 2010	2002-2008	58	58	25	33	...	...	The First Affiliated Hospital of Xinjiang Medical University
Lu Shengwei et al	June, 2010	2005. 6-2009. 3	62	62	29	33	1.5	1.5	The First Affiliated Hospital of Guangxi Medical University
Meng Fanxin et al	June, 2010	2000. 1. 1-2010. 1. 1	92	53\$	28	25	3	3.3	Peking Union Medical College Hospital
Yue Wenliang et al	May, 2010	2004. 1-2009. 4	112	112	66	46	...	...	The First Affiliated Hospital of China Medical University
Qiu Jian et al	May, 2010	2003-2010	120	120	36	84	£	£	The Second Xiangya Hospital, Central South University
Jiang Lanshan et al	March, 2010	2004-2009	23	23	6	17	< 2	< 6	Mian yang Central Hospital
Zhang Jinglan et al	2010	NG	90	90	44	46	...	...	Beijing Anzhen Hospital, Capital Medical University
Ding Hao et al§	October, 2009	2001. 1. 1-2008. 12. 31	30	30	8	22	1	1	The First Affiliated Hospital of Anhui Medical University
Chen Weiqing et al§	August, 2009	2001. 6-2008. 1	31	23	4	19	3.2	3.2	Tianjin Medical University General Hospital
Zhang Yongjie et al§	June. 2009	2002. 1-2007. 7	42	42	12	30	2.7	2.7	Central Hospital City of Zibo
Chen Yushuai et al§	December, 2008	2000. 7-2005. 12	54	54	20	34	2.7	2.7	First Affiliated Hospital of China Medical University
Tang Xiaobin et al	September, 2008	2002. 1-2007. 7	223	223	82	141	2.7	2.7	Beijing Anzhen Hospital, Capital Medical University
Ye Jinming et al	September, 2008	2006. 2-2007. 6	75	72	49	23	...	...	Zhejiang Hospital & Zhongshan Hospital, Fudan University
Du Qingguo et al	2007	2002. 2-2006. 2	37	37	14	23	...	...	The First Affiliated Hospital, Chongqing Medical University
Yao Chen et al	January, 2006	2003.10-2004. 10	34	34	15	19	0.9	0.9	The First Affiliated Hospital, Sun Yat-sen University
Dong Yifei et al	December, 2005	2003. 1-2005. 4	23	23	3	20	...	...	Lanzhou General Hospital, Lanzhou Command, PLA
Shu Chang et al	June, 2003	1999-2002	26	21	7	14	...	...	The Second Xiangya Hospital, Central South University
Feng Rui et al†	February, 2003	1997. 3-2002. 3	157	157	115	42	...	...	Changhai Hospital, Second Military Medical University
Fu Weiguang et al	2003	1997. 9-2001. 10	92	92	31	61	2	2	Zhongshan Hospital, Fudan University
Guo Wei et al	June, 2000	1993. 6-1999. 8	52	52	20	32	...	...	General Hospital, People's Liberation Army(PLA)

Note:

\$: There were 92 patients involved with sufficient reported data. However only 53 had follow-up data, which we included in our analysis.

£: Although the study reported the survival curve, sufficient data was not reported.

§: Despite mean follow-up time being given the studies did not provide a detailed number for death or survival.

†: This study mainly discussed EVAR and OSR affecting renal function.

Table 3. Characteristics of the 11 studies included in the meta-analysis.

Racial/ethnic group	EVAR (N = 13,399)	OSR (N = 19,080)	Total (N = 32,479)
Western population	12, 774 (41.1%)	18, 300 (58.9%)	31,074
Chinese population	625 (44.5%)	780 (55.5%)	1,405

Note: EVAR: elective endovascular repair; OSR: elective open surgical repair.

were described as non-randomized prospective or retrospective data. A subsequent meta-analysis (Lovegrove et al., 2008) ameliorated this data limitation, but its long-term (more than five years for EVAR) results were not convincing. The EVAR cure rates are controversial with regard to medium-and long-term outcomes, such as all-cause mortality, aneurysm-related mortality and re-intervention. The recent Dutch Randomized Endovascular Aneurysm Management (DREAM) (De Bruin et al., 2010) and EVAR-1 trial results (United Kingdom EVAR Trial Investigators et al., 2010) with regard to EVAR versus OSR have shed light on long-term outcomes. Specifically, six years after randomization, EVAR and OSR of abdominal aortic aneurysm resulted in similar survival rates. The rate of secondary interventions was significantly higher for EVAR than for OSR.

More importantly, the prevalence of AAAs is different in Western and Chinese populations. Additionally, the promotion of EVAR occurred later in China than in Western countries. Although the results of domestic studies (Fu et al., 2003) confirmed that EVAR is suitable for Chinese patients, three areas based on domestic studies are still inconclusive: 1) the Chinese morbidity rate, 2) the morphological specificity of aneurysms and 3) a diameter of aneurysm ≥ 5.5 cm as indication for the domestic treatment of abdominal aortic aneurysms. Although it is generally acknowledged that EVAR accords greater benefit than OSR to AAA patients, studies comparing the two techniques in Western versus Chinese populations are sparse. Furthermore, short term outcomes in EVAR versus OSR were not confirmed by meta-analyses based on Chinese patients. Consequently, material for the comparison of both treatments is still lacking.

To better understand the effects of EVAR in Chinese populations, we analyzed data on AAA repair from the literature published during the period that EVAR was introduced. Thus, the aim of our current investigation was to carry out a systematic review of the studies in which EVAR was compared to OSR in the treatment of AAAs patients from Western countries (North America and Europe) and China.

2. Evidence acquisition

2.1 Literature search

A systematic literature search of Western articles on EVAR and OSR of infrarenal AAA was carried out by two independent researchers (Y. H and J. Z) using the MEDLINE (PubMed), journals@Ovid Full Text, and BIOSIS previews databases (OVID). The following Medical Subject Headings (MeSH) search terms were used: aortic aneurysm, abdominal, vascular surgical procedures, stents, and randomized controlled trial. In addition, exploding keywords included endovascular, comparative, and mortality. The corresponding search strategy is provided (Supplementary files 1). We limited our search to reports on human subjects

in the English language. We searched databases for articles published between November 1991 (because (Parodi et al., 1991) published their results on the first clinical application of endovascular repair for abdominal aortic aneurysm in 1991) and December 2018. Every relevant article retrieved had its references thoroughly checked. Following this the articles were entered into the ISI WEB OF KNOWLEDGE: WEB OF SCIENCE database (1991 to 2018) to find the references cited in order to find any related literature. Relevant medical journals were also thoroughly checked.

We performed a comprehensive search of the Chinese literature. The key words abdominal aortic aneurysm and endovascular repair were used in a comprehensive search of the CBMDisc (Chinese Biomedical Database) and CNKI (Chinese National Knowledge Infrastructure) databases. All Chinese studies on abdominal aortic aneurysm treatment between January 1998 (because in 1998, Jing and colleagues (Jing et al., 1998) published their initial article of endovascular repair AAA in China) and 24th December 2018 were identified. Reference lists were also examined and relevant articles added to the list. Furthermore, several Chinese journals were hand searched from 1998 to 2015, specifically the Chinese Journal of Practical Surgery, Chinese Journal of General Surgery, Chinese Medical Journal, and Chinese Journal of Vascular Surgery.

2.2 Selection

Inclusion criteria: Randomized controlled, prospective, and retrospective, studies were included if they met the following criteria:

(a): patients diagnosed with an infrarenal and non-ruptured abdominal aortic aneurysm undergoing elective endovascular repair were compared with patients undergoing elective open surgical repair;

(b): at least 20 patients;

(c): sufficient data (> 25 percent of predefined variables) such as patient baseline characteristics and short- and long-term outcomes;

(d): in the case of multiple reports from the same institution, only the most rigorous published report was used to avoid duplication of data;

(e): however, when two or more studies from the same institution reported on medium- or long-term outcomes on the same patients, the results from all linked studies were included synergistically.

Excluded criteria: articles were excluded if they:

(a): did not report outcomes in a comparable fashion;

(b): included patients with other aortic pathologies such as ruptured abdominal aortic aneurysms, thoracic aortic aneurysms and aortic dissections;

(c): contained insufficient data (< 25 percent of predefined variables);

Table 4. Reviewers' judgements about each methodological quality item included in the Four Western Randomized Controlled Trial (RCT) Studies.

Study	Year of Publication	EVAROSR		Cochrane Reviewer's Handbook							Jadad		
				Adequate sequence generation	Allocation concealment	Blinding	Withdrawals and drop outs	ITT	Risk bias	of Randomization	Double blinding	Withdrawals and drop outs	Jadad's score
Soulez et al	August, 2005	20	20	computer	met	unclear	unmet	unclear	B	2	1	0	3
DREAM	October, 2004	171	174	computer	met	double blinding	met	met	A	2	2	1	5
	June, 2005												
	May, 2010												
EVAR-1	August, 2004	543	539	computer	met	double blinding	met	met	A	2	2	1	5
	June, 2005												
Cuypers et al	April, 2001	57	19	computer	met	double blinding	met	met	A	2	2	1	5

Note: ITT(intent-to-treat)

Table 5. Baseline Characteristics of Patients Undergoing Endovascular Repair (EVAR) or Open Surgical Repair (OSR) for Abdominal Aortic Aneurysms (AAA) in Western and Chinese Studies.

Characteristic	Region	No. of studies	EVAR		OSR		OR/WMD 95% CI		Weight	P
			n (%)*	N	n (%)*	N				
Male Gender-No.	Chinese	10	338 (86.2)	392	411 (83.7)	491	1.007	0.678, 1.497	9.25	0.972
	Western	34	10, 870 (87.7)	12,290	14,708 (81.9)	17,954	1.692	1.460, 1.961	90.75	< 0.001
	Total	44	11,208 (88.4)	12,682	15,119 (82.0)	18,445	1.614	1.408, 1.849	100	< 0.001
Mean age-Year [I]	Chinese	11	67.31	313	63.69	433	3.63	0.959, 6.302	10.5	0.008
	Western	19	73.33	8,399	70.68	8,541	2.413	1.845, 2.982	89.5	< 0.001
	Total	30	70.32	8,712	67.19	8,974	2.555	2.007, 3.103	100	< 0.001
Hypertension-No.	Chinese	12	209 (51.7)	404	327 (56.9)	575	1.139	0.711, 1.826	14.85	0.588
	Western	28	7,127 (67.3)	10,593	10,091 (63.3)	15,934	1.096	0.961, 1.251	85.15	0.17
	Total	40	7,336 (66.7)	10,997	10,418 (63.1)	16,509	1.098	0.966, 1.249	100	0.153
Hyperlipidemia-No.	Western	14	1,169 (46.1)	2,534	1,459 (43.8)	3,333	1.213	0.928, 1.587	100	0.158
	Chinese	10	57 (14.4)	395	55 (10.8)	510	1.364	0.899, 2.070	12.44	0.144
Diabetes Mellitus-No.	Western	29	1,533 (14.4)	10,658	2,244 (13.9)	16,123	1.248	1.028, 1.514	87.56	0.025
	Total	39	1,590 (14.4)	11,053	2,299 (13.8)	16,633	1.266	1.063, 1.507	100	0.008

Table 5. Baseline Characteristics of Patients Undergoing Endovascular Repair (EVAR) or Open Surgical Repair (OSR) for Abdominal Aortic Aneurysms (AAA) in Western and Chinese Studies.

Characteristic	Region	No. of studies	EVAR		OSR		OR/WMD	95% CI	Weight	P
			n (%)*	N	n (%)*	N				
Cardiac Disease-No.	Chinese Δ	8	136 (42.1)	323	122 (35.0)	349	1.404	0.799, 2.466	13.58	0.238
	Western†	24	3,923 (47.3)	8,301	2,485 (28.2)	8,807	1.137	0.899, 1.438	57.94	0.283
	Western§	13	902 (14.1)	6,390	622 (6.3)	9,820	2.901	1.995, 4.218	28.48	< 0.001
	Total§	NC	NC	NC	NC	NC	1.522	1.236, 1.873	100	< 0.001
Pulmonary Disease-No. £	Chinese	6	41 (17.2)	239	50 (18.2)	274	1.069	0.661, 1.728	10.9	0.787
	Western	26	3,448 (33.0)	10,438	3,997 (25.6)	15,642	1.515	1.209, 1.899	89.1	< 0.001
	Total	32	3,489 (32.7)	10,677	4,047 (25.4)	15,916	1.458	1.182, 1.799	100	< 0.001
	Chinese	4	10 (5.8)	172	10 (6.6)	152	1.041	0.352, 3.074	6.65	0.942
Renal Disease-No. Φ	Western	18	564 (6.1)	9,283	833 (5.8)	14,280	1.27	0.902, 1.789	93.35	0.171
	Total	22	574 (6.1)	9,455	843 (5.8)	14,432	1.251	0.903, 1.733	100	0.178
	Chinese	5	25 (11.4)	220	23 (7.4)	311	1.726	0.626, 4.762	10.21	0.292
	Western	12	361 (6.6)	5,477	731 (6.1)	12,014	1.287	1.091, 1.517	89.79	0.003
Cerebrovascular Disease-No.	Total	17	386 (6.8)	5,697	754 (6.1)	12,325	1.258	1.019, 1.553	100	0.033
	Chinese	7	71 (45.8)	155	152 (53.5)	284	0.723	0.473, 1.106	16.64	0.135
	Western	21	3,145 (70.4)	4,465	2,950 (64.5)	4,571	1.057	0.813, 1.375	83.36	0.677
	Total	28	3,216 (69.6)	4,620	3,102 (63.9)	4,855	0.999	0.793, 1.258	100	0.992
Smoking-No. ‡	Chinese	6	77 (28.9)	266	73 (24.3)	300	0.788	0.496, 1.251	24.21	0.312
	Western	10	1,005 (19.5)	5,162	2,576 (22.4)	11,493	1.163	0.764, 1.771	75.79	0.482
	Total	16	1,082 (19.9)	5,428	2,649 (22.5)	11,793	1.057	0.742, 1.505	100	0.76
	Chinese	10	54.31	247	60.31	387	-5.793	(-7.993, -3.594)	13.69	< 0.001
Peripheral Vascular Disease-No.	Western	15	57.71	4,790	60.41	2,768	-2.491	(-3.307, -1.675)	86.31	< 0.001
	Total	25	56.01	5,037	60.36	3,155	-2.932	(-3.697, -2.168)	100	< 0.001
	Chinese	10	54.31	247	60.31	387	-5.793	(-7.993, -3.594)	13.69	< 0.001
	Western	15	57.71	4,790	60.41	2,768	-2.491	(-3.307, -1.675)	86.31	< 0.001
Aneurysm Diameter-mm¶	Western	15	57.71	4,790	60.41	2,768	-2.491	(-3.307, -1.675)	86.31	< 0.001
ASA > II-No. †	Western	9	1,783 (74.4)	2,395	1,646 (67.4)	2,441	2.637	1.307, 5.322	100	0.007

Note: *: The number of patients for dichotomous data (values in parentheses are percentages) and average for continuous data. NC: not calculated.

OR: odds ratio. WMD: weighted mean difference. CI: confidence interval.

¶: Outcomes presented as weighted mean difference.

Δ: Reported in studies as coronary artery disease/ischaemic heart disease from Chinese studies.

†: Reported in studies as coronary artery disease/ischaemic heart disease from Western studies.

§: Reported in studies as congestive heart failure from Western studies.

£: Not calculated because a portion of the total number of patients with cardiac disease combined both CAD and CHF.

Φ: Reported in studies as chronic obstructive pulmonary disease/ pulmonary disease.

‡: Reported in studies as smoking present/history of smoking.

†: Denotes American Society of Anesthesiologists, the total scores more than II

P values in bold denote statistical significance.

Table 6. Procedures for Endovascular Repair and Open Surgical Repair for Abdominal Aortic Aneurysms (AAA) in Chinese and Western Studies.

Characteristic	Region	No. of studies	EVAR		OSR		OR/WMD	95% CI	Weight	P
			n	N	N	N				
General anaesthetic-No.	Western	7	582 (36.1)	1,612	1313 (94.3)	1,393	0.055	0.014, 0.216	100	< 0.001
	Chinese	15	183.8	416	261.9	601	-82.192	(-101.793, -62.590)	45.88	< 0.001
Operative time-min.	Western	14	149.9	3,395	184.1	8,127	-33.557	(-45.179, -21.935)	54.12	< 0.001
	Total	29	166.9	3,811	223	8,728	-56.659	(-67.483, -45.836)	100	< 0.001
Blood Loss-ml.	Chinese	15	156.8	416	965.3	601	-640.454	(-751.134, -529.774)	54.23	< 0.001
	Western	13	341.6	1,820	1463.5	1,937	-989.139	(-1.2e + 0.3, -828.958)	45.77	< 0.001
Blood Transfusion-ml.	Total	28	249.2	2,236	1214.4	2,538	-829.134	(-952.542, -705.726)	100	< 0.001
	Chinese	13	52.3	388	694.5	547	-517.31	(-595.507, -439.112)	75.5	< 0.001
ICU Stay-hr	Western	4	70.1	784	383	783	-312.695	(-62.053, -3.337)	24.5	0.048
	Total	17	61.2	1,172	538.8	1,330	-471.091	(-541.958, -400.223)	100	< 0.001
Postoperative Stay-days	Chinese	11	31.1	275	64.3	330	-29.397	(-37.048, -21.747)	47.57	< 0.001
	Western	13	16.7	3,697	75.5	8,472	-52.785	(-65.280, -40.290)	52.43	< 0.001
Length of Stay-days	Total	24	23.9	3,972	69.9	8,802	-42.479	(-51.105, -33.853)	100	< 0.001
	Chinese	11	11.1	256	14.9	387	-4.179	(-5.828, -2.531)	46.96	< 0.001
	Western	6	3.9	2,063	8.4	2,602	-4.556	(-5.469, -3.643)	53.04	< 0.001
	Total	17	7.5	2,319	11.7	2,989	-4.457	(-5.140, -3.773)	100	< 0.001
	Chinese	5	24	199	26.5	234	-2.68	(-5.182, -0.178)	10.8	0.036
	Western	6	4.8	5,175	10.6	7,018	-5.608	(-6.176, -5.039)	89.2	< 0.001
	Total	11	14.4	5,374	18.6	7,252	-5.3	(-5.850, -4.750)	100	< 0.001

Note: ICU stay: intensive care unit.

(d): did not meet the criteria for abstracts and unpublished data;

(e): were confined to select subgroups of patients (e.g. octogenarians).

2.3 Predefined outcomes

Complications were classified and graded according to the reporting standards of the Ad Hoc Committee for Standardized Reporting Practices in Vascular Surgery of the Society for Vascular Surgery International Society for Cardiovascular Surgery. Three classes of complications (systemic, local-nonvascular, and local-vascular or implant-related) and three grades of severity (mild, moderate, and severe) were used. A reintervention was defined as any surgical or endovascular procedure that was related to the primary aneurysm-repair procedure.

2.4 Assessment of risk of bias

We aimed to reduce the possibility of publication bias through the following methods: searches of meeting abstracts, theses, dissertations and contacting authors for any additional unreported data. When necessary, we contacted the authors of the original papers to receive further information. The risk of bias was assessed using the methods of (Lundh and Gøtzsche, 2008).

2.5 Validity assessment

Randomized controlled trials (RCTs): the quality of the methodology was assessed independently by two reviewers (F.S. and Y.H.) using the Cochrane risk of bias tool (Higgins et al., 2011). The risk of bias was divided into low (all criteria met), moderate (one or more criteria met), and high (no criteria met). In addition, the quality of the methodology used in each study

was evaluated by the same authors, using the system described by (Jadad et al., 1996). Non-randomized studies (NORS): The quality of non-randomized studies was assessed by two reviewers (F. S. and Y. H.) using the MINORS scoring system describe by (Slim et al., 2003). This method uses (Moher et al., 1999) items for comparative studies with each item scored 0, 1 or 2 corresponding to not reported, inadequately reported, and adequately reported, respectively. Whether RCTs or NORS, discrepancies in ratings were resolved by discussion between the two reviewers (C. J. and Y. H.). Additionally, when discrepancies arose, a third party (J. Z.) was consulted.

2.6 Data abstraction

After the initial assessment for eligibility, two authors (H. Y. and S. W.) independently abstracted the data from the primary sources. They independently reviewed all the articles. Different results between the two authors were resolved by consensus. For each study we extracted rudimentary information including author(s), study design, journals published, geographical location, date published, etc. The following predefined variables were recorded using an electronic extraction form: preoperative characteristics and postoperative outcomes (we conducted a separate meta-analysis for two different postoperative time periods: short-term and mid-long term). Follow-up visits were scheduled 30 days and 12, 24, 36 months and 5 years after the procedure. Any death or complications occurring within 30 days after the original procedure were defined as short-term, and any death, complication and reintervention occurring more than 30 days after the original procedure were defined as mid-long term. For the results during

Table 7. End Points and Operative Complications of Patients Undergoing Endovascular Repair (EVAR) or Open Surgical Repair (OSR) for Abdominal Aortic Aneurysms (AAA) in Chinese and Western Studies.

Characteristic	Region	No. of studies	EVAR		OSR		OR	95% CI	Weight	P
			n (%)	N	n (%)	N				
Cardiac Complications-No.	Chinese	13	20 (5.2)	382	55 (9.8)	563	0.683	0.405,1.153	9.15	0.154
	Western	19	240 (3.7)	6,437	642 (7.3)	8,852	0.411	0.348, 0.485	90.85	< 0.001
	Total	32	260(3.8)	6,819	697 (7.4)	9,415	0.43	0.367, 0.504	100	< 0.001
Pulmonary Complications-No.	Chinese	15	17 (3.9)	435	60 (9.3)	646	0.552	0.324, 0.940	11.58	0.029
	Western	18	152 (3.4)	4,427	573 (11.4)	5,044	0.27	0.222, 0.328	88.42	< 0.001
	Total	33	169 (3.5)	4,862	633 (11.1)	5,690	0.293	0.245, 0.352	100	< 0.001
Renal Complications-No.	Chinese	9	12 (3.5)	341	21 (4.5)	468	0.74	0.336, 1.631	11.82	0.455
	Western	19	529 (5.8)	9,056	747 (7.8)	9,617	1.081	0.765, 1.529	88.18	0.659
	Total	28	541 (5.8)	9,397	768 (7.6)	10,085	1.029	0.752, 1.408	100	0.859
Cerebrovascular Complications-No.	Chinese	4	3 (1.9)	158	7 (3.2)	216	1.011	0.223, 4.588	10.52	0.988
	Western	11	31 (0.9)	3,183	39 (1.3)	3,113	0.836	0.508, 1.374	89.48	0.479
	Total	15	34 (1.0)	3,341	46 (1.4)	3,329	0.854	0.534, 1.367	100	0.511
Wound Complications-No.	Chinese	9	9 (2.3)	388	24 (5.0)	481	0.743	0.353, 1.564	25.48	0.433
	Western	16	148 (4.1)	3,617	384 (10.0)	3,856	0.72	0.357, 1.453	74.52	0.359
	Total	25	157 (3.9)	4,005	408 (9.4)	4,337	0.686	0.390, 1.208	100	0.192
Limb ischaemia/ embolization-No.	Chinese	8	11 (4.4)	251	7 (1.8)	396	1.539	1.004, 3.198	26.23	0.049
	Western	8	50 (2.5)	1,979	52 (2.5)	2,075	0.914	0.462, 1.809	73.77	0.796
	Total	16	61 (2.7)	2,230	59 (2.4)	2,471	1.106	0.923, 1.303	100	0.41
Re-intervention-No.	Western	6	188 (13.4)	1,401	103 (6.5)	1,581	1.962	0.932, 4.176	100	0.08
	Chinese	12	8 (2.3)	352	22(4.1)	542	0.733	0.342, 1.572	7.04	0.425
30 day mortality-No.	Western	33	218 (1.8)	12,133	674 (3.8)	17,817	0.481	0.378, 0.612	92.96	< 0.001
	Total	45	226 (1.8)	12,485	696 (3.8)	18,359	0.49	0.399, 0.602	100	< 0.001

the follow-up period in the long-term analysis we used data on all-cause mortality at 1, 2-3 and more than 5 years after discharge, the rate of re-intervention at 1 year and more than 4 years and aneurysm-related mortality at 2-3 years and more than 5 years.

2.7 Statistical analysis

This study was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (available at <http://www.prisma-statement.org/>) This study was also conducted in accordance with the Quality Reporting of Meta-analyses (QUROM) guidelines (Moher et al., 1999) and reporting Meta-analyses of observational studies (MOOSE) guidelines (Stroup et al., 2000). We measured the odds ratio (OR) for dichotomous data, reported with 95% confidence intervals (CI). In addition, we calculated the weighted mean difference (WMD) with 95% CI for continuous data. The analysis was performed by comparing EVAR with OSR; an OR greater than 1 denoted that an event was more common following EVAR. We used the fixed effect model if evidence of nonsignificant heterogeneity was found. If there was evidence of significant heterogeneity, a random effects model as described by (DerSimonian and Laird, 1986) was used, and the degree of heterogeneity was assessed using the I^2 (Lovegrove et al., 2008) test. I^2 (Lovegrove et al., 2008) values of 25%, 25-50% and > 50% were considered to represent small, medium and large amounts of inconsistency.

A comparison between Western and Chinese cohorts using the method of subgroups was performed to analyze the diversity be-

tween the two groups. However, for the mid-long term survival outcomes the hazard ratios (HRs), Kaplan-Meier survival curves and log-rank test P value (Tierney et al., 2007) were extracted from individual studies. Furthermore, pooling of individual log HRs was performed using the method described by (Parmar et al., 1998) Subgroup analysis and HRs which were calculated by a statistical method were used to contrast the two cohorts. An HR less than 1 indicated a better survival rate for EVAR.

Publication bias was assessed using a funnel plot. Furthermore, to assess heterogeneity, Egger's test (Egger et al., 1997) and graphical exploration with Egger's regression asymmetry plot were used to evaluate publication bias. We used the results of 30-day mortality and all-cause mortality for mid-long term as the effect index, because this was the most standardized outcome presented in most studies.

A difference for $P < 0.05$ was considered statistically significant. All statistical analyses were conducted using spreadsheet software (Microsoft Excel 2007; Microsoft, Redmond, Washington, USA) and performed using the meta. ado module of STATA (version 11.0, College Station, Texas, USA)

3. Evidence synthesis

3.1 Trial flow

The Western literature search identified 172 studies for potential inclusion in the meta-analysis; 127 of these papers were excluded: 96 did not compare endovascular repair (EVAR) with open surgical repair (OSR), four papers described only a selected patient subgroup such as obese or octogenarian patients, another 18

papers contained insufficient data, and nine overlapped with included studies from the same institution. Thus, 45 papers met our inclusion criteria. Trial flow charts are provided in Fig. 1. The trial flow chart for Chinese language articles is provided in Fig. 2.

3.2 Studies selected

Details of the selected articles for this study are given in (Table 1) for the English language articles. The included 45 papers assessed outcomes following elective AAA repair: three reports from the Dutch Randomized Endovascular Aneurysm Management (DREAM) Trial study (Blankensteijn et al., 2005; De Bruin et al., 2010; Prinssen et al., 2004) and 3 articles from the EVAR trial 1 study (EVAR trial participants, 2005; Greenhalgh et al., 2004; United Kingdom EVAR Trial Investigators et al., 2010) were treated as one study each for the purpose of analysis because in each case one of the reports represented a mid-long term follow-up study subsequent to an initial report. In addition, because Johnson et al. (2006) and Bush et al. (2006), Carpenter (Carpenter and Endologix Investigators, 2004) and Wang et al. (2008), Matsumura et al. (2003) and Peterson et al. (2007) reported from the same institution; they were treated as one for the purpose of analysis. The former dates were replenished respectively by Bush, Wang and Peterson, consequently these both fitted into our study. In total, 38 studies published up to January 2011 ultimately met our predefined inclusion criteria. These articles were published from June 1998 to June 2010 and used patients enrolled from 1994 to 2007. These articles consisted of four randomized controlled trials, 12 prospective non-randomized trials, and 22 retrospective conducted studies; 13 were from Europe and 25 were from North America.

The twenty-one Chinese language papers contained 1,405 AAA procedures. The Chinese language articles were published between 1993 and 2010 (Table 2).

3.3 General demographics

Within the Western papers, a total of 31,074 elective AAA procedures were reported, of which 12,774 were EVAR and 18,300 were OSR. By comparison, a total of 1,405 operations were performed for unruptured AAA in the Chinese papers, of which 625 were EVAR and 780 were OSR. There are significant difference across racial groups, with Chinese patients more likely to receive EVAR compared to Western patients ($P = 0.012$) (Table 3).

3.4 Risk of bias assessment

Table 4 shows that four RCT studies adequately performed all methodological requirements as assessed by the Cochrane risk of bias tool and Jadad's scoring system, and three were considered to be at low risk of bias, with the remaining trial was graded at moderate risk. Furthermore, for Western non-randomized studies, 19 (21 papers) of 34 studies (37 papers) achieved an ideal score of 24 points. However, 15 studies did not report follow-up data and therefore did not meet the criterion for the item "loss of follow-up less than 5%" and were thus allotted 22 points.

3.5 Quantitative data synthesis

Patient characteristics:

In Table 5 we provide the demographic and clinical characteristics of all the patients included in this review, broken down by treatment group. A significant difference was present for sex in Western cohorts, with more male patients in the EVAR group ($OR = 1.692$, $P < 0.001$) whereas this difference was not present

in Chinese cohorts ($OR = 1.007$, $P = 0.972$). Whether Western or Chinese, patients in the EVAR group were significantly older than those in the OSR group ($P < 0.001$ and $P = 0.008$), nevertheless, the age range was larger in Chinese cohorts ($WMD_{Western}$ 2.413 years versus $WMD_{Chinese}$ 3.63 years). The maximum diameter of the aneurysms in the EVAR group was significantly smaller than in the OSR group for both cohorts ($P < 0.001$ and $P < 0.001$). Also, the range was larger for the Chinese cohorts than for the Western cohorts ($WMD_{Western}$ -2.491 mm versus $WMD_{Chinese}$ -5.793 mm).

We found that the EVAR group had a higher rate of co-morbid conditions in Western studies, with a statistically significant difference in three of the baseline medical conditions; these were diabetes mellitus ($OR = 1.248$, $P = 0.025$), respiratory disease ($OR = 1.515$, $P < 0.001$) and cerebrovascular disease ($OR = 1.287$, $P = 0.003$). However, these differences were not present in the Chinese cohort. In addition, Western patients with the American Society of Anesthesiologists classification III or IV were more likely to receive elective EVAR than OSR ($OR = 2.637$, $P = 0.007$). Of note, thirteen Western studies showed a statistically significant difference in the odds ratio ($OR = 2.901$, $P < 0.001$) for congestive heart failure between the EVAR group and OSR group. No significant difference, however, was found in other aspects of cardiac disease in the Western and Chinese cohorts.

3.6 Surgical and Perioperative Characteristics:

Characteristics for surgical and post-operative data are given in Table 6. Information on the type of anesthesia was available for seven Western studies: 36.1 percent of 1,612 patients receiving endovascular repair received a general anesthetic compared with 94.3 percent of 1,393 patients receiving open surgical repair ($OR = 0.055$, $P < 0.001$). Most of the surgical characteristics showed significant differences between the EVAR and OSR groups both for Chinese and Western cohorts. The duration of a typical EVAR procedure (mean 183.8 minutes versus 149.9 minutes) was significantly different than that of a typical OSR procedure (mean 261.9 versus 184.1 minutes) ($WMD_{Chinese}$ -82.2 minutes versus $WMD_{Western}$ -33.6 minutes, $P < 0.001$ versus $P < 0.001$, respectively).

Considering either the volume of blood loss or blood transfusion, the superiority of endovascular repair over open surgical repair was clear. Specifically, in the Western cohort the range of blood loss between EVAR and OSR was even larger ($WMD_{Western}$ -989.1 ml versus $WMD_{Chinese}$ -640.5 ml). Nevertheless, the range of blood transfusion between the two procedures was even smaller ($WMD_{Western}$ -312.7 ml versus $WMD_{Chinese}$ -517.3 ml), namely, contract by OSR, Chinese patients undergoing EVAR were transfused less blood (approximately a unit) than Western patients.

In addition, patients who underwent EVAR experienced significantly shorter stays in the intensive care unit (ICU) and the hospital for both Western and Chinese cohorts. The Western patients who underwent EVAR had significantly shorter stays in the ICU ($WMD_{Western}$ -52.785 hours, $P < 0.001$) and significantly shorter duration in the hospital ($WMD_{Western}$ -5.608 days, $P < 0.001$) than Chinese patients.

3.7 End Point and Adverse Events

Table 7 presents a more detailed overview of the reported complications; the Western pooled estimate of the cardiac complica-

tion rate for EVAR was significantly lower than that for OSR (OR-Western = 0.411, $P < 0.001$). This superiority for EVAR was not replicated in the Chinese cohorts, however. Whether in Chinese or Western cohorts, endovascular repair was associated with a significant reduction in postoperative respiratory complications, however, the Chinese complication rate for the respiratory system (OR = 0.270, $P < 0.001$) in the EVAR group was lower than in Western patients (OR = 0.552, $P = 0.029$) receiving EVAR. There was no significant difference in the incidence of renal, cerebrovascular, and wound complications. Furthermore, Chinese limb ischaemia or embolization were more common (ORChinese = 1.539, $P = 0.049$) in patients receiving EVAR, although Western studies did not contain this difference. In addition, the pooled estimate of 30-day mortality in Western studies for the EVAR group was significantly lower than that for the OSR group (OR = 0.481, $P < 0.001$), however this difference was not present in the Chinese cohort (OR = 0.733, $P = 0.425$) (Fig. 3).

3.8 Medium-long term outcomes

3.8.1 Pooled ORs for Western studies

In Western countries the amount of medium-long term research in this field is far more than in China and it is therefore far easier to reach a satisfactory outcome using Western studies. Consequently, we have primarily based the analysis of the mid-long term comparison of the two AAA treatment methods on Western studies.

Fifteen, four, and nine articles reported data for all-cause mortality at one year, two-three years and more than five years, respectively. In an analysis of the pooled data we found no significant difference in all-cause mortality at one year, 2-3 years and more than five years (OR = 0.932, 95% CI: 0.723-1.203; $P = 0.590$ for one year) (OR = 0.850, 95% CI: 0.407-1.774; $P = 0.665$ for 2-3 years) (OR = 1.301, 95% CI: 0.982-1.724; $P = 0.067$ for more than 5 years) respectively (Fig. 4).

Eight and three articles, respectively, compared aneurysm-related mortality for medium term aneurysm-related mortality and more than 5 years between endovascular repair group and open surgery groups, which showed that medium-term (mean

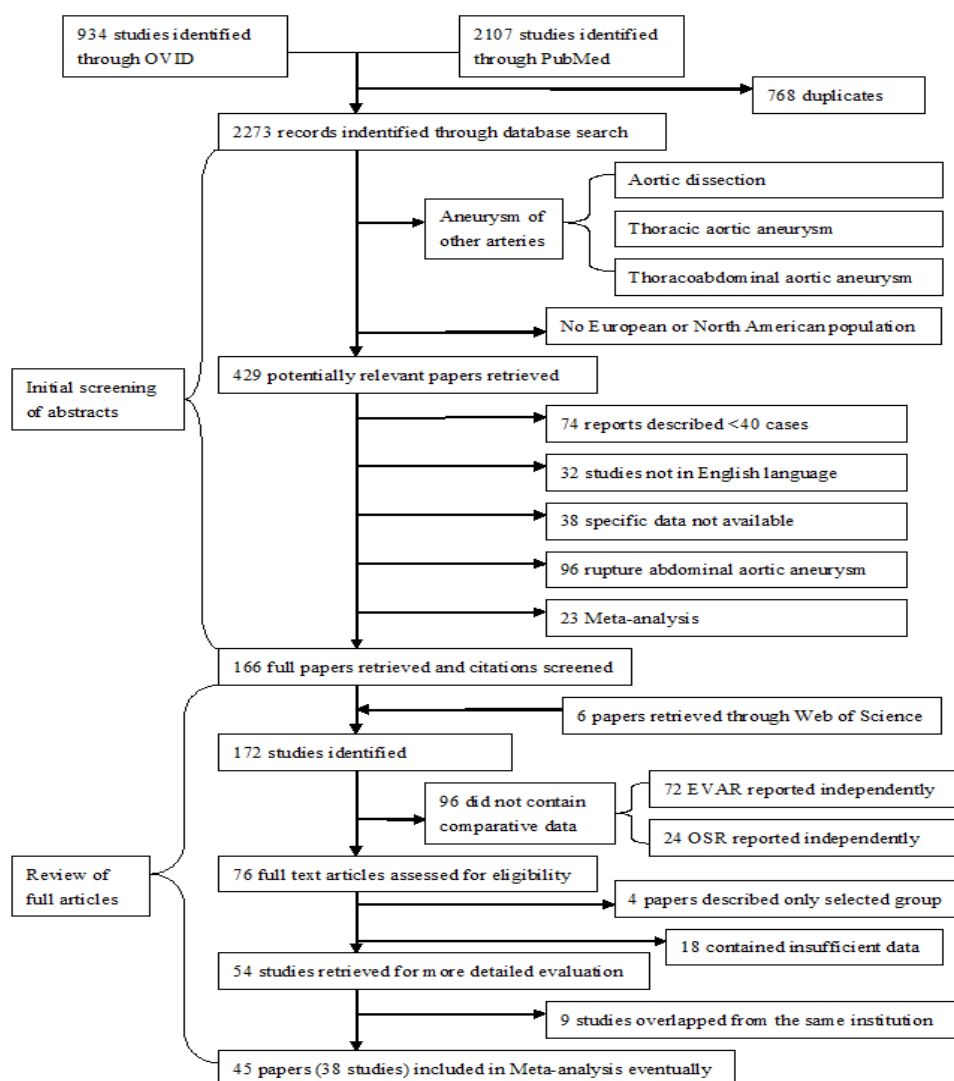


Figure 1. Flow diagram of this meta-analysis in accordance with the QUOROM statement from Western studies.

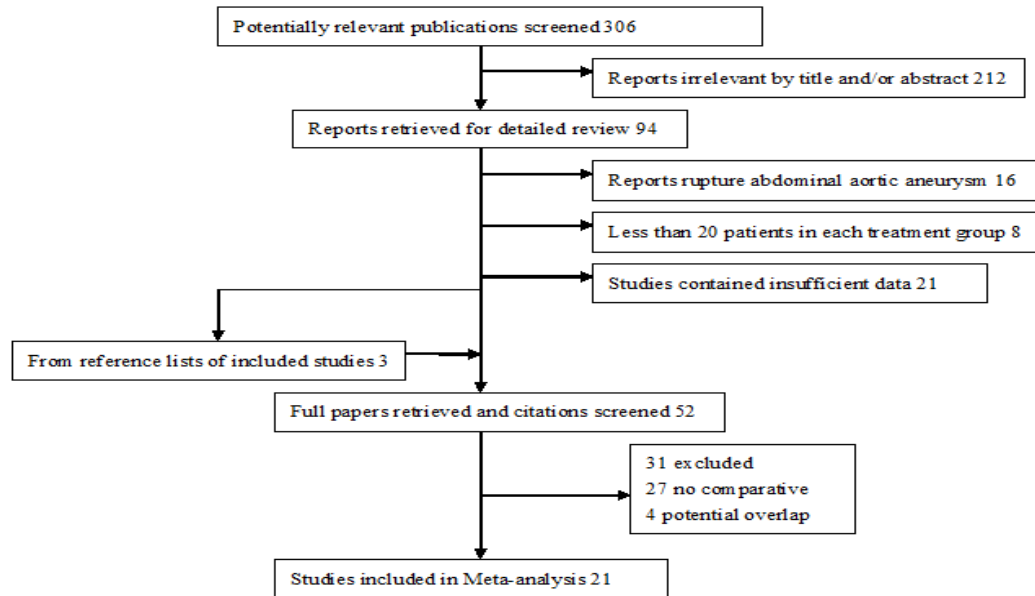


Figure 2. Flow diagram of this meta-analysis in accordance with the QUOROM statement from Chinese studies.

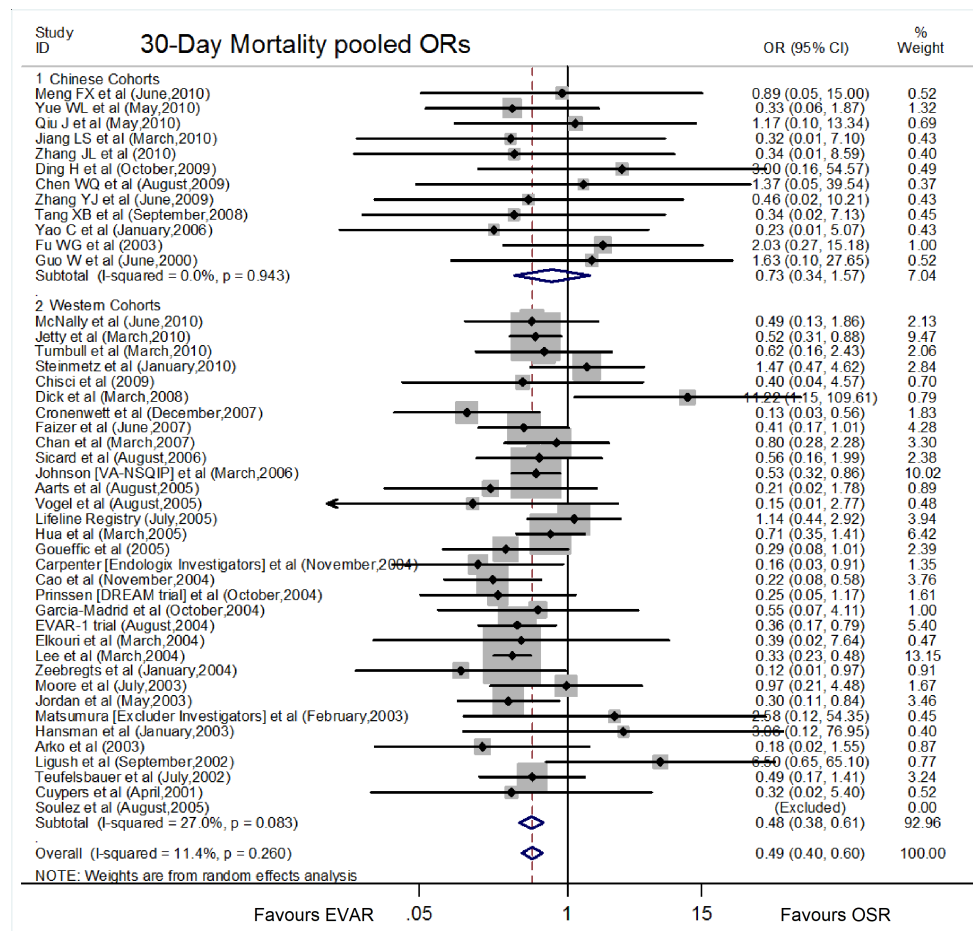


Figure 3. Forest plot of 30-day mortality following endovascular aortic aneurysm repair (EVAR) or open surgery repair (OSR) to the treatment of elective abdominal aortic aneurysms (AAAs) between China and Western countries.

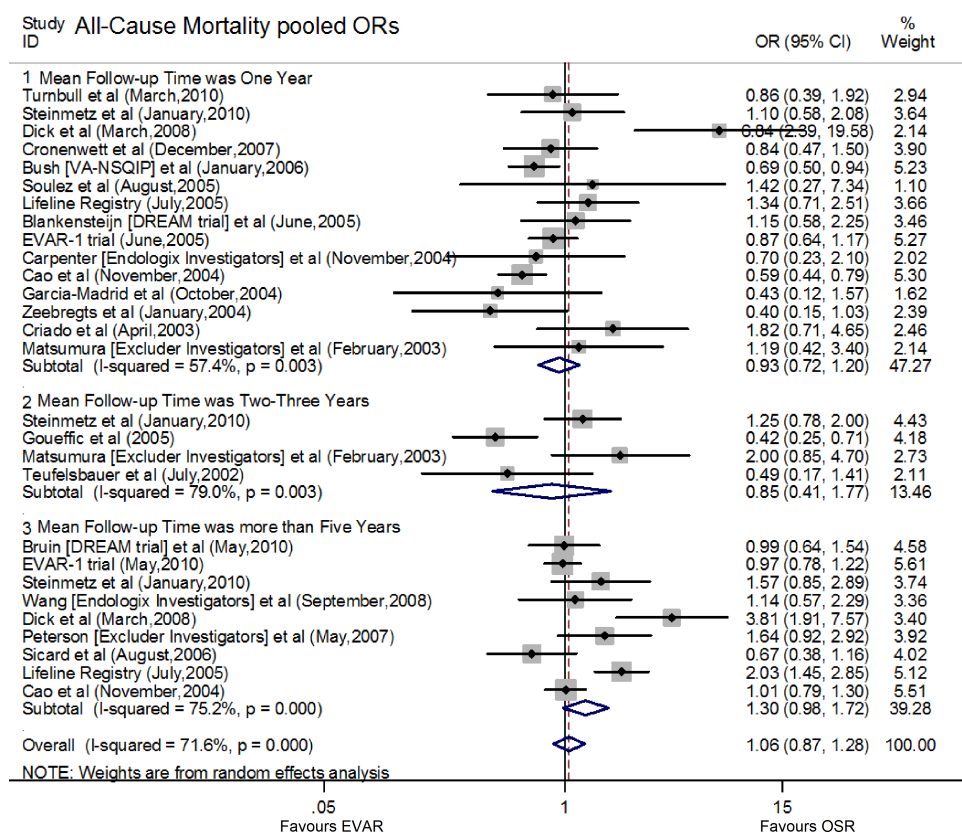


Figure 4. Forest plot of all cause mortality following endovascular aortic aneurysm repair (EVAR) or open surgery repair (OSR) during follow-up time at one year, 2-3 years and more than five years after discharge.

follow-up time was 2-3 years) aneurysm-related mortality (OR = 0.566, 0.402-0.796; $P = 0.001$) was significantly lower after EVAR compared to OSR. Endovascular repair did not, however, influence long-term (mean follow-up time was more than five years) aneurysm-related mortality (OR = 0.639, 95% CI: 0.360-1.133; $P = 0.125$) (Fig. 5).

An analysis of eight studies with 1-year follow-up data showed that patients receiving EVAR were more likely to experience re-intervention, (OR = 2.042, 95 % CI: 1.467-2.843; $P < 0.001$) compared to OSR patients. Additionally, an analysis of four studies involving 3,214 participants with 3-year follow-up data showed that EVAR patients were more likely to experience re-intervention (OR = 4.107, 95% CI: 2.304-7.318; $P < 0.001$) than OSR patients (Fig. 6).

3.8.2 Pooled HRs for Western and Chinese studies

Although there were few studies reporting aneurysm-related mortality and the rate of re-intervention, we included the three Chinese articles which reported all-cause mortality (Fig. 7). These studies had a mean follow-up time of 25.4 to 37.6 months and involved 265 participants (95 in EVAR, 170 in OSR). The medium-long term all-cause mortality to a maximum follow-up period of 4 years was not significantly higher (HR = 1.173, 95% CI: 0.895-1.538; $P = 0.247$) for the EVAR group than the OSR group.

Data on all-cause mortality were reported in seventeen trials from Western studies. These studies included 9,994 participants, with a mean follow-up time ranging from 19.2 to 76.8 months. We

found no statistically significant difference in the risk of all-cause mortality between the EVAR and OSR patients (HR = 1.026, 95% CI: 0.956-1.100; $P = 0.483$).

3.9 Publication bias

Publication bias was evaluated with a funnel plot of all analyses reporting on 30-day mortality following elective abdominal aortic aneurysm repair. all the points were within the trilateral region (Fig. 8A). Furthermore, publication bias was evaluated using the Begg test (result: $P = 0.122$) and Egger test (result: $P > |t|$ was 0.920), and the Egger linear regression asymmetry plot frequently tended to show the presence of publication bias (Fig. 8B). The plot displays that the regression line passes through the point of origin, which may indicate the absence of bias.

4. Discussion

Patient racial and ethnic variations reflect racial disparities in socioeconomic status and patient-level differences (Chen et al., 2006). The use of different providers (Bach et al., 2004; Baicker et al., 2005; Byrd and Clayton, 2002) and different treatment by the same provider (Schulman et al., 1999) have been shown to result in disparate practice patterns and outcomes depending on race and ethnicity. Additionally, race and ethnicity have been shown to predict disparities, treatment variations and postoperative outcomes in the surgical arena (Andrew and Elixhauser, 2000; Epstein et al., 2010; Jha et al., 2005). Less is known about racial/ethnic differences in cardiovascular procedure outcomes. Although large

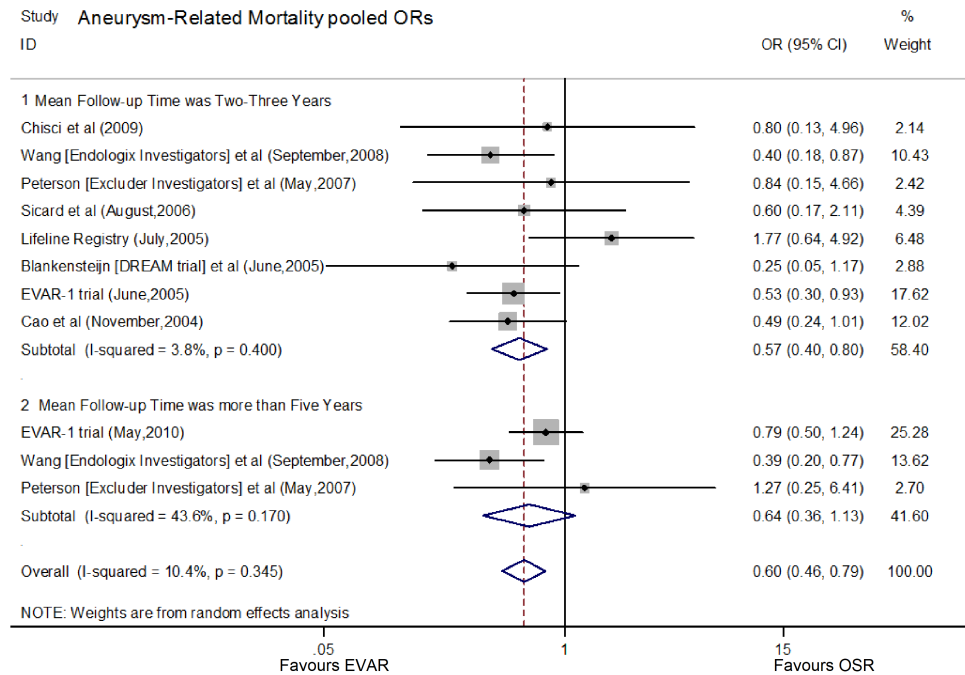


Figure 5. Forest plot of aneurysm-related mortality following endovascular aortic aneurysm repair (EVAR) or open surgery repair (OSR) during follow-up time at 2-3 years and more than five years after discharge.

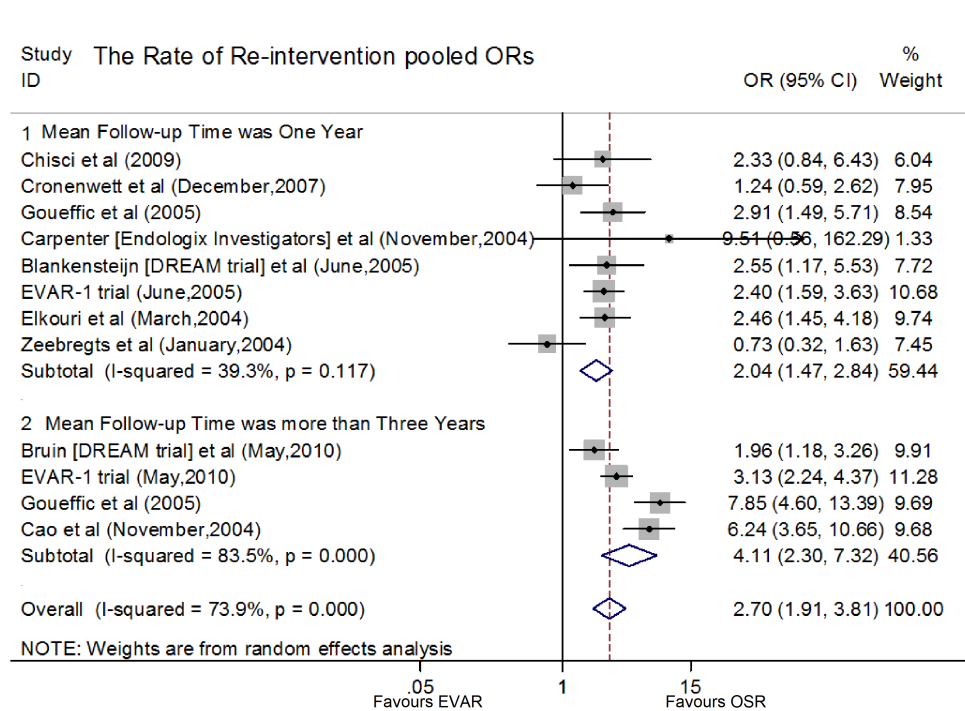


Figure 6. Forest plot of rate of re-intervention following endovascular aortic aneurysm repair (EVAR) or open surgery repair (OSR) during follow-up time at one years and more than three years after discharge.

and multiregional cohort studies have shown that minority patients such as black and Hispanic patients are more likely to receive procedures in low-volume hospitals, these studies focus on diverse cardiovascular procedures for which there is a documented association between the disparities of ethnicity and hospital or surgeon

volume (Epstein et al., 2010; Trivedi et al., 2006) Unfortunately, even though subsequent research has shown that racial and ethnic disparities account for differences of treatment in AAA, these studies were restricted to a specific racial comparison (black versus white or Hispanic versus white subjects).

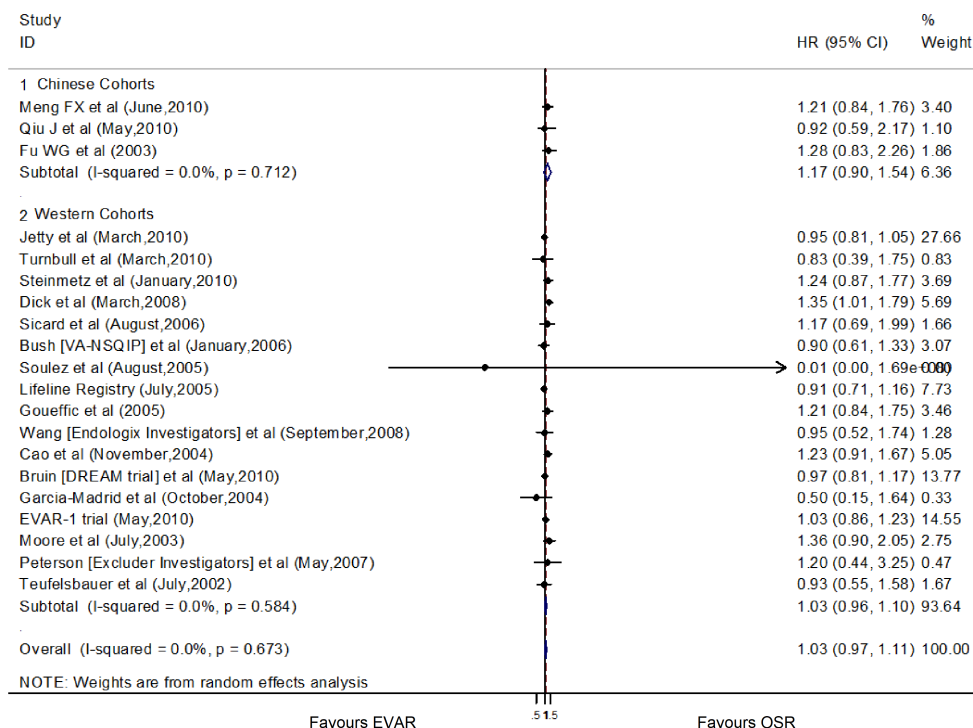


Figure 7. Forest plot of all-caused mortality pooled HR (hazard ratio) following endovascular aortic aneurysm repair (EVAR) or open surgery repair (OSR) during follow-up time.

Many studies (Lovegrove et al., 2008) assess the short- or mid-long term differences between EVAR and OSR and some of these studies reported on a large number of samples. Despite this, to the best of our knowledge, this is the first systematic review of the different outcomes due to ethnicity - specifically Western and Chinese - following EVAR or OSR for elective abdominal aortic aneurysms. Therefore, our study had some important strengths. This is the most (to our knowledge) comprehensive meta-analysis of patients treated for AAA, using a broad study sample captured through an electronic retrieval system. We used strict inclusion criteria and excluded patients with non-elective aneurysms (ruptured AAAs and inflammatory AAAs) because including them would adversely affect the analysis of the prognosis of patients, which would have distorted the study results. In addition, although heterogeneity is often a concern in meta-analyses, little evidence of heterogeneity was observed throughout our study. We performed a systematic search using multiple databases and extracted data in duplicate.

In this study we report the major differences between Chinese and Western cohorts in the treatment and outcomes of two major AAA procedures. We found a significantly low short-term respiration complication after EVAR. Importantly, the examination of short-term outcomes confirmed that EVAR is associated with significantly low 30-day mortality in Western countries. The counterpart as well as China, nevertheless, EVAR has not exposed this superior. The racial/ethnic disparities we found can be partially explained by differences in the use of EVAR techniques, socioeconomic status and co-morbidities (Osborne et al., 2009). Additionally, several factors of providers (low-mortality, high-quality and

high-volume hospitals) may be responsible for these differences in the outcomes of AAA procedures.

Chinese patients were more likely to receive EVAR (44%) compared to Western patients (41%). This difference in treatment may be due to four separate mechanisms. First, these disparities could be attributed to confounding provider-patient factors such as decision making (Rathore and Krumholz, 2004) in provider care and differences in patient preferences (e.g., prevalence and morbidity of AAAs). Second, these disparities in treatment could be caused by anatomical differences in AAAs (e.g., EVAR suitability) between Chinese and Western patients. Third, these disparities could be caused by differences in the type and quantity of co-morbidities (e.g., cardiac and pulmonary morbidities with AAAs) that influence the treatment decision. Finally, objective factors due to socioeconomic status (e.g., insurance status) may lead to the disparities in treatment. Patient mortality may be influenced by these disparities of treatment directly and indirectly. This study demonstrated a trend toward worse early outcomes of EVAR among Chinese subjects (30-day mortality was 2.3%) which is not significant diversity versus OSR.

A possible explanation for the disparity in AAA repair is patient preferences and provider-patient factors. Although little is known about the prevalence of AAAs among the racial and ethnic groups represented in this meta-analysis, two studies (Salem et al., 2009; Spark et al., 2001) have demonstrated a very low incidence of aneurysms in Asian subjects. This may provide some evidence to the prevalence of Chinese aneurysms. Unfortunately, their study was only a comparative research of the population confined to a specific geographical area (Leicester, Bradford in Eng-

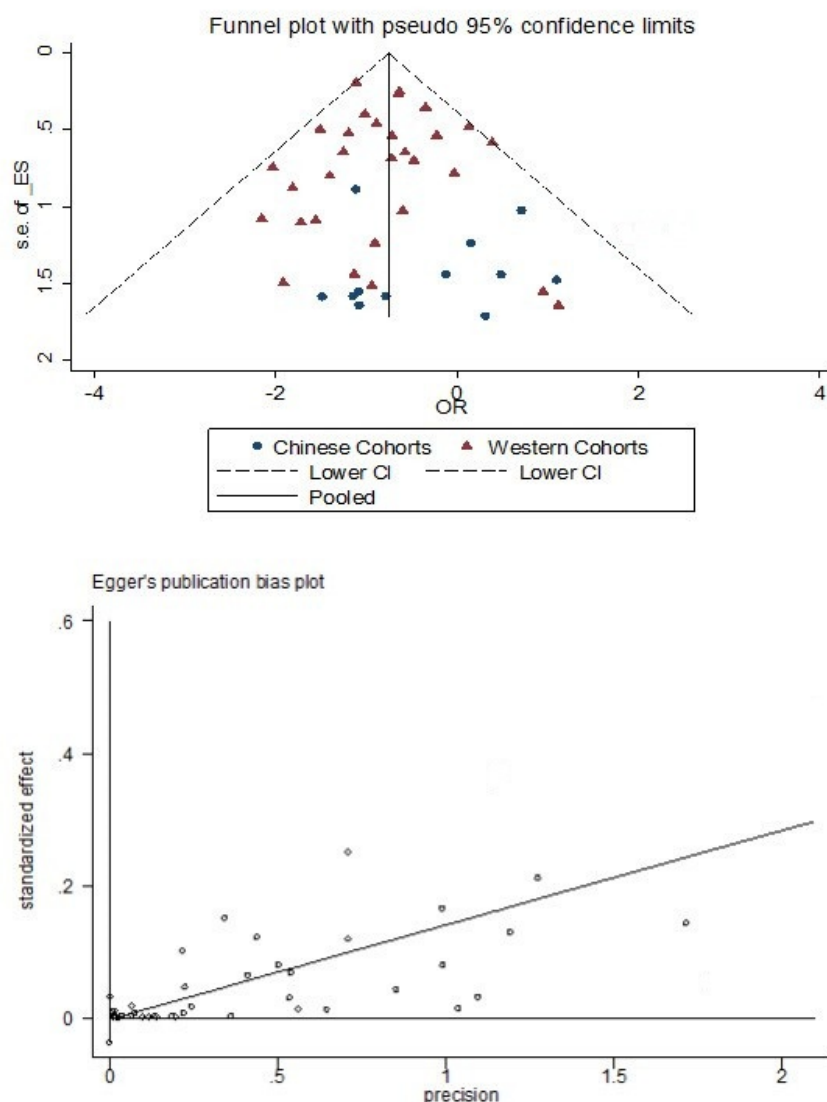


Figure 8. a. The funnel plot to assess publication bias from 30-day mortality data from Chinese and Western studies. b. Egger's publication bias plot to assess publication bias from 30-day mortality data from Chinese and Western studies.

land). Perhaps Chinese patients will receive more medical attention for EVAR and therefore receive the minimally invasive procedure because of the lower prevalence of disease among Chinese patients compared to Western patients.

Anatomical variation may be responsible for racial disparities in the treatment and mortality of AAAs. Although most variation is unexplained by observable patients and provider factors, differences of ethnicity alone may be treated differently because of unmeasured factors such as anatomical variation and aneurysm size (Osborne et al., 2009). However, no previous studies to date have reported anatomical differences in AAAs between racial and ethnic groups, especially Chinese patients. Although there is no evidence available, through our analysis and previous work (Fu et al., 2003) it is plausible that Chinese patients may be predisposed to AAAs that are suitable for EVAR which may partially explain the disparity in treatment. A previous study (Osborne et al., 2009) suggested that the racial and ethnic disparity in mor-

tality can be partially (29%) explained by differences in patient comorbidities. Therefore, this result also suggested that Chinese patients may have more challenging aortic anatomies (e.g., shorter common iliac arteries) and more access-related and device-related complications compared to Western patients (Tam et al., 2018; Wu et al., 2014).

A previous study (Osborne et al., 2009) also demonstrated that 26% of the disparity in mortality is due to differences in socioeconomic status. The type of insurance such as Medicare, Medicaid, private insurance and self-pay in American patients could partially represent differences in socioeconomic status. With regard to treatment disparities, they demonstrated that insurance status predicts disease severity at the time of treatment; however, after discharge, the outcomes are similar among insurance categories. Furthermore, uninsured and Medicaid patients possess different health statuses compared to Medicare and private insurance patients, which adversely influence peri-operative mortality. The

Chinese literature does not clearly report the health insurance type and the expense of AAAs, but Asian patients were more likely to be enrolled in Medicare or uninsured, even though their socioeconomic status was higher than Black patients (Epstein et al., 2010).

Our study has a number of limitations. First, the method of reporting - including reporting of the frequency of events - was variable, making data aggregation challenging. Three studies have been adjusted systemically in the following fashion: (1) data from the same medical center has been reported by (Bush et al., 2006; Johnson et al., 2006) separately. Johnson reported the one-year follow-up data through 5 propensity groups, while Bush reported the survival analysis curve. Compared with Bush, Johnson provided a more complete analysis on the preoperative data. So we analyzed the preoperative data from Johnson's paper while using survival analysis results from Bush's paper. (2) (Carpenter and Endologix Investigators, 2004) published a paper in 2004 and Wang et al. (2008) published a paper in 2008 with both papers reporting the same outcome, but with different follow up times (Wang followed up as long as 81 months which was much longer than Carpenter). Therefore, we used Wang's data to compute the HR value but used Carpenter's data to compute the OR value. (3) Although (Matsumura et al., 2003; Peterson et al., 2007) both reported their follow-up data, but we used Peterson's data to evaluate the long-term efficacy because of its different follow-up period and its analysis of survival data.

There were several other limitations. Our study data was limited to the available literature - although we used the VA (Veterans Affairs) and NIS (Nationwide Inpatient Sample) US databases, it would have been better to have had more available data. We couldn't categorize the data according to racial/ethnic group. The Chinese literature data may include the Chinese population data. Our enrollment criterion was that both EVAR and OSR were reported in a comparative way; this made our Chinese sample much smaller than the Western sample. Additionally, Chinese papers published are much less than the Western literature. Finally, because this analysis was mainly based on data from Western and Chinese populations, additional investigation in other populations is still needed.

In conclusion, we found that Chinese patients were more likely to receive EVAR than OSR, and the post-procedure short-term mortality was significantly lower for EVAR than for OSR in Western patients but not in Chinese patients. Endovascular repair can be applied to Chinese patients with a reasonable safety margin. Further work is needed to explore the causes of these treatment differences.

Authors' contribution statement

Feng Shi and Yanshuo Han contributed to conception and design; Yuchen He, Yanshuo Han, Shiyue Wang and Jian Zhang contributed to acquisition of data, or analysis and interpretation of data; and Yanshuo Han and Chao Ji were involved in drafting the manuscript or revising it critically for important intellectual content. All authors have given final approval on the version to be published.

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Conflict of interest

The authors declare no conflict of interest in preparing this article.

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Supplementary files 1

Pubmed

("Aortic Aneurysm, Abdominal" [Mesh] OR "AAA" [tiab] OR (("Aneurysm" [Mesh] OR "Aneurysm" [Tw] OR "Aneurysms" [Tw]) AND ("Abdomen" [Mesh] OR "Abdominal Cavity" [Mesh] OR "Abdomen" [Tw] OR "Abdominal" [Tw] OR "Aorta, Abdominal" [Mesh] OR ("Aorta" [Tw] OR "Aortic" [Tw]) AND ("abdominal" [tw] OR "abdomen" [tw]))) AND ("Endovascular Procedures" [majr] OR "Endovascular" [ti] OR "EVAR" [ti] OR "eEVAR" [ti] OR "Minimal invasive" [ti] OR "Minimally-invasive" [ti] OR "Minimally invasive" [ti] OR "Stentgraft" [ti] OR "Stent-graft" [ti]) AND ("Open" [ti] OR "OSR" [ti] OR "OAR" [ti] OR "OR" [ti] OR "OS" [ti])

OID

("Abdominal aorta aneurysm"/ OR "AAA".ti,ab. OR ("Aneurysm"/ OR "Aneurysm".mp. OR "Aneurysms".mp.)

AND ("Abdomen"/ OR "Abdominal Cavity"/ OR "Abdomen".mp. OR "Abdominal".mp. OR "Abdominal aorta"/ OR ("Aorta".mp. OR "Aortic".mp.) AND ("abdominal".mp. OR "abdomen".mp.)) AND (exp *"Endovascular surgery"/ OR "Endovascular".ti. OR "EVAR".ti. OR "eEVAR".ti. OR "Minimal invasive".ti. OR "Minimally-invasive".ti. OR "Minimally invasive".ti. OR "Stentgraft".ti. OR "Stent-graft".ti.) AND (*"open surgery"/ OR "Open".ti. OR "OSR".ti. OR "OAR".ti. OR "OR".ti. OR "OS".ti.)

Web of Science

TS = ("AAA" OR ("Aneurysm" OR "Aneurysms") AND ("Aorta" OR "Aortic") AND ("abdominal" OR "abdomen")) AND TI = ("Endovascular" OR "EVAR" OR "eEVAR" OR "Minimal invasive" OR "Minimally-invasive" OR "Minimally invasive" OR "Stentgraft" OR "Stent-graft") AND TI = ("Open" OR "OSR" OR "OAR" OR "OR" OR "OS")