Systematic Review

Open surgical repair for chronic type B aortic dissection: a systematic review

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Background: The treatment of chronic type B aortic dissection (CBAD) remains complicated. Thoracic endovascular aortic repair (TEVAR) has supplanted open surgical repair (OSR) as the preferred surgical treatment for CBAD. Despite TEVAR's superior short-term results, much less is understood about its long-term outcomes. As much of the understanding of OSR originates from historical report, contemporary series, with modern surgical techniques and technologies, may present an alternative to TEVAR. The present systematic review will assess the short- and long-term outcomes of historic and contemporary series of OSR for CBAD.

Methods: Electronic searches were performed using six databases from their inception to March 2014. Relevant studies with OSRs for chronic type B dissection were identified. Data were extracted by two independent reviewers and analyzed according to predefined clinical endpoints. Studies were sub-classified into the pre-endovascular (historic series) and endovascular era (contemporary series) depending on whether the majority of cases were performed after 1999.

Results: Nineteen studies were identified for inclusion for quantitative analysis. Pooled short-term mortality was 11.1% overall, and 7.5% in the nine contemporary studies. Stroke, spinal cord ischemia, renal dysfunction, and reoperation for bleeding were 5.9%, 4.9%, 8.1%, and 8.1%, respectively, for the contemporary series. Absolute late reintervention was identified in 13.3% of patients overall, and in 11.3% of patients in the contemporary series. Aggregated survival at 1-, 3-, 5-, and 10-years of all patients were 82.1%, 74.1%, 66.3%, and 50.8%, respectively.

Conclusions: OSR for chronic type B dissection in the contemporary era offers acceptable results. Management approaches should be considered carefully, taking into account both short-term and long-term complications. More research is required to clarify specific indications for OSR and TEVAR in chronic type B dissections.

Keywords: Open surgical repair (OSR); thoracic endovascular aortic repair (TEVAR); chronic type B dissection; descending aorta

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Background

The optimal management of chronic type B aortic dissections (CBAD) remains controversial. Since the first widely published reports of endovascular stent-grating for descending aortic aneurysms in 1994 by Dake and colleagues (1), and its subsequent use in descending aortic dissections in 1999 (2,3), thoracic endovascular aortic repair (TEVAR) has supplanted open surgical repair (OSR) as the preferred treatment option for type B dissections. While there exists clear indications exist for TEVAR in acute complicated type B dissections, uncertainty persists regarding the superiority of TEVAR over OSR for CBAD (4-6).

The success of TEVAR is dependent on the thromboexclusion of the false lumen, as persistent false lumen perfusion can result in aortic expansions of up to 4 mm/year (7). In the chronic phase, there appears to be less consistent TEVAR-led aortic remodeling than in acute dissections, with total false lumen thrombosis ranging between 38-93%, and 15-17% of patients experiencing an increase in false lumen size in at least one location (8-11). While the short-term procedural benefits of an endovascular approach are undeniable compared to open surgery, its long-term advantage for CBAD is unclear. Indeed, a recent expert consensus on treatment of chronic dissections with endovascular stent-grafts concluded that TEVAR does not reduce aortic ruptures or increase life expectancy (4). OSR, on the other hand, eliminates the risk of aneurysm-related death in the treated segment. While historical surgical series have demonstrated high mortality rates (12-17), contemporary series, utilizing modern surgical techniques, report a positive trend towards more favorable patient outcomes.

The contemporary results of open surgery for type B dissections are critical to understanding the role of TEVAR in descending aortic pathologies, particularly given the unabated enthusiasm for endovascular interventions. The aim of the present study was to assess and summarize the outcomes of open surgical repair for chronic type B aortic dissections, with particular focus on contemporary data in the current endovascular era.

Methods

Literature search

Electronic searches were performed using Ovid Medline, Embase, Cochrane Central Register of Controlled Trials (CCTR), Cochrane Database of Systematic Reviews (CDSR), ACP Journal Club, and Database of Abstracts of Review of Effectiveness (DARE) from their date of inception to March 2014. To achieve the maximum sensitivity of the search strategy and identify all studies, we combined the terms: "aorta" and "dissection" and "chronic" as either key words or MeSH terms. The reference lists of all retrieved articles, as well as review articles, were reviewed for further identification of potentially relevant studies. All identified articles were systematically assessed using the inclusion and exclusion criteria.

Eligibility criteria

Eligible studies for the present systematic review included those in which patient cohorts underwent open surgery for chronic dissections of the descending aorta (Stanford type B or DeBakey type III dissection). Cases that involved the ascending aorta or aortic arch (type A dissections) or only the abdominal aorta were excluded. Studies were included regardless of the extent of the descending dissection. Chronicity was defined as greater than 14 days following symptomatic presentation or documentation of intimal entry tear.

Studies that did not include the predetermined primary endpoint of 30-day or in-hospital mortality were excluded. When institutions published duplicate studies with accumulating numbers of patients or increased lengths of follow-up, only the most complete reports were included for quantitative assessment at each time interval. Reports that presented primary endpoint data on 10 or more patients were included. All publications were limited to those involving human subjects and in the English language. Abstracts, case reports, conference presentations, editorials, and expert opinions were excluded. Review articles were omitted because of potential publication bias and duplication of results.

Data extraction and critical appraisal

All data were extracted independently from article texts, tables and figures by two investigators (R.P.D.S. and T.W.). Data was subsequently reviewed and tabulated by another investigator (D.H.T.). Discrepancies between the two reviewers were resolved by discussion and consensus with the third investigator (D.H.T.). Methodological quality was assessed using a 18-item validated quality appraisal checklist specifically developed for the evaluation of case series (18). Various elements of the study, including study objective, population, interventions, outcome measures, statistical analysis, results, conclusions, and competing interests were assessed. The final results were reviewed by the senior investigator (T.D.Y.).

Statistical analysis

Standard descriptive statistics were used to summarize demographic and baseline data of eligible patients. Data were presented as raw numbers with percentage or mean ± standard deviation as appropriate unless otherwise indicated. Pooled averages were estimated using the random-effects model proposed by DerSimonian and Laird (19). Pooled values were calculated for outcomes that were reported in

Table 1 Summary of study characteristics of open surgery for chronic type B aortic dissection

Era	First author	Year of publication	Institution	Study period	Study type	N	Follow up (years)
Historic series	Reul	1975	Texas Heart Institute, USA	1964-1974	OS, R	42	10†
	Jex	1986	Mayo Clinic, USA	1962-1986	OS, R	35	4.1
	Gandjbakhch	1990	Pitie's Hospital, France	1976-1987	OS, R	12	5
	Glower	1990	Duke University Medical Center and Stanford University Medical Center, USA	1975-1988	OS, R	22	13†
	Kawashima	1993	Osaka University School of Medicine, Japan	1977-1991	OS, R	28	8
	Fann	1995	Stanford University Medical Centre, USA	1963-1992	OS, R	34	5.1
	Safi	1998	Methodist Hospital, USA	1991-1996	OS, R	92	NR
	Okita	1999	National Cardiovascular Center, Japan	1979-1998	OS, R	79	5.2
	Zanetti	1999	General Regional Hospital, Italy	1993-1996	OS, R	20	NR
	Miyamoto	2008	Hyogo College of Medicine, Japan	1983-2002	OS, R	40	9.8
Contemporary series	Nienaber	1999	University Hospital Eppendorf, Germany, and Policlinico S. Orsola-Malpighi, Italy	1997-1998	OS, R	12	1
	Goksel	2008	Istanbul University, Turkey	1996-2004	OS, R	15	3
	Takagi	2010	Fujita Health University, Japan	2004-2009	OS, R	39	NR
	Zoli	2010	Mount Sinai Hospital, USA	1994-2007	OS, R	104	7.7
	Mutsuga	2010	Nagoya University Hospital, Japan	2000-2009	OS, R	33	4.8
	Pujara	2012	Cleveland Clinic, USA	2000-2008	OS, R	169	1.9
	Corvera	2012	Indiana University, USA	1995-2009	OS, R	93	4.6
	Nozdrzykowski	2013	Leipzig Heart Center, Germany	2000-2010	OS, R	15	3.5M
	Conway	2014	Lenox Hill Hospital, USA	1999-2010	OS, R	86	4.6M

†, upper range of follow-up; M, median; OS, observational study; R, retrospective; NR, not reported.

at least 50% of studies and for at least 50% of total patients. Studies were further categorized into 'pre-endovascular' (historic series) and 'endovascular' era (contemporary series) based on whether more than half of its study period was after 1999, when the first series of stent-grafting for descending aortic dissections were widely reported (2,3).

Individual patient survival data was reconstructed using an iterative algorithm that was applied to solve the Kaplan-Meier equations originally used to produce the published graphs. This algorithm, as provided by Guyot and colleagues, uses digitalized Kaplan-Meier curve data to find numerical solutions to the inverted Kaplan-Meier equations (20). This algorithm assumes constant censoring and was calculated in R software (v.3.1.0). The reconstructed patient survival data were then aggregated to form combined survival curves.

Evidence of publication bias was sought using the methods of Egger *et al.* (21) and Begg *et al.* (22). If studies appear to be missing in areas of low statistical significance, then it is possible that the asymmetry is due to publication bias. If studies appear to be missing in areas of high statistical significance, then publication bias is a less likely cause of funnel asymmetry. Intercept significance was determined by the *t*-test suggested by Egger *et al*. All statistical analyses were conducted with Comprehensive Meta-analysis v2.2 (Biostat Inc, Englewood, NJ, USA). P values <0.05 were considered statistically significant.

Results

Quantity and quality of evidence

A total of 1,574 unique records were identified through electronic searches of the seven databases (*Figure S1*). After excluding records based on abstract, 225 full-text articles were assessed according to the inclusion and exclusion criteria. Nineteen relevant studies were included in the present review (2,14-17,23-36).

All of the included studies were retrospective observational series (Level 4 evidence) (*Table 1*). Only six series had greater than 50 patients (range, 79-169); the median size of studies was 35. Of the 19 studies, nine were categorized as being in the 'endovascular era' (contemporary series) (2,28,30-36), with only five studies that included patient cohorts solely after 1999. The landmark study by Nienaber *et al*. was included in the contemporary cohort as its patients were matched controls with the one of the first stent-grafting series at the same institution (2). One study published in 2008, which included a study period of 1983-2002, was excluded from the 'endovascular era' category as its follow-up data suggested the majority of cases were performed prior to 1999 (29).

Chronic dissection was explicitly defined as ≥2 weeks after symptomatic presentation in most studies, except one, which defined it as 3 weeks (15). Chronicity was not defined in 10 studies (2,24,26,27,29-32,34,36). All but two studies used the Stanford classification for aortic dissections (14,24,27).

The quality of the studies ranged from low to moderately high. Common limitations included recruitment from single-centers, failure to acknowledge competing interests, and lack of reporting on proportion lost to follow-up or length of follow-up.

Demographic and operative techniques

The demographic details are summarized in *Table 2*. In 19 studies, 970 patients underwent open surgery for CBAD. Overall, 76.5% of patients were male, with a weighted mean age of 57.9 years. Eighty-six percent of patients were hypertensive (2,17,23,25,30,31,33-36), 0-24% of patients had a history of stroke, while 0-33% of patients had pulmonary disease and 11.0% had renal dysfunction (2,16,17,23,28,30,31,33-36). Marfan syndrome was present in 12.0% of patients (2,17,23,26,28,30-33,35,36).

Surgical indication for the majority of cases included aneurysms ≥50 mm (27,34), >55 mm (30), >60 mm (26), unspecified growth rate or dilation limit (14,15,23,28,31,35), malperfusion (15,28,31,34,35), presence of symptoms (14,23,27,28,31,34,35), or rupture (26,31,35) (*Table 3*). Nine studies did not specify indications for surgery (2,16,17,24,25,29,32,33,36). In series from institutions that also reportedly performed TEVAR, indications for open repair included extensive involvement of the aorta (33,35) or connective tissue disease (35). Another study indicated that TEVAR was only a 'complication-specific' indication (28). The remaining six studies from the endovascular era did not provide any evidence that they also perform endovascular repairs (29-32,34,36), while another did not state indication for OSR (2).

Thoracoabdominal involvement was identified in 48.5% of patients in contemporary studies, and 39.1% in historical series (overall, 45.8%). The majority of repairs involved graft replacement of the diseased aorta, while some only closed the entry tear and plicated the aneurysm. A wide range of spinal cord protection strategies were used, including CSF drainage, selective intercostal reimplantation and hypothermic circulatory arrest.

Mortality and morbidity

Early mortality at 30 days for the entire cohort was 11.1% (range, 0-33%) (*Table 4*). Stroke occurred in 5.6% of patients (range, 0-13%), while 4.9% of patients experienced spinal cord ischemia (range, 0-13%). Postoperative renal dysfunction affected 11.9% of patients (range, 0-33%). Subsequent re-exploration for bleeding was required for 9.9% of patients (range, 0-33%).

In contemporary studies, mortality was 7.5% compared to 15.2% for series in the pre-endovascular era. While the incidence of strokes and spinal cord ischemia was slightly higher for contemporary (stroke, 5.9% *vs*. 5.3%; SCI, 5.1% *vs*. 4.6%), these studies had better renal outcomes (8.1% *vs*. 13.5%).

Medium-term outcomes

Individual patient survival data of 458 patients was reconstructed from the Kaplan-Meier survival curves of 7 studies (26,28-31,33,35). Analysis of this data using Kaplan-Meier methods demonstrate 1-, 2-, 3-, 5-, and 10-year survival of 82.1%, 77.1%, 74.1%, 66.3%, 50.8%, respectively (*Figure 1*). Late absolute reintervention rate was 13.3% for the entire cohort, but 11.3% for the studies in the endovascular era.

Publication bias

Begg's rank correlation method (P=0.239) and Egger's weighted (P=0.151) regression method were performed to assess publication bias in the literature. Although both tests suggest publication bias was not an influencing factor when mortality was selected as an outcome measure for all 19 included studies, visual inspection of the contour-enhanced funnel plot suggests small study effect exists (*Figure S2*). Using the imputed Trim and Fill method, the point estimate for mortality increased slightly from 11.1% to 11.7%.

Table 2 Summary of patient baseline demographics

	First author	Age	Males [%]	Hypertension [%]	Prior stroke [%]	Marfan [%]	Pulmonary disease [%]	Diabetes [%]	Renal dysfunction [%]	Prev aortic surgery [%]
Historic series	Reul	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Jex	55±2	24 [69]	27 [77]	1 [3]	4 [11]	0	1 [3]	2 [6]	NR
	Gandjbakhch	NR	NR	NR	NR	NR	NR	NR	NR	1 [8]
	Glower	56±3	16 [73]	NR	NR	NR	NR	NR	2 [9]	NR
	Kawashima	52±11	21 [75]	NR	NR	NR	NR	NR	NR	NR
	Fann	56±14	27 [79]	25 [74]	0	4 [12]	4 [12]	4 [12]	3 [9]	NR
	Safi	NR	75 [82]	75 [82]	NR	NR	NR	NR	NR	NR
	Okita	57±8	NR	NR	NR	0	NR	NR	NR	NR
	Zanetti	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Miyamoto	60±12	29 [73]	NR	NR	NR	NR	NR	NR	NR
Contemporary series	Nienaber	56±12	10 [83]	10 [83]	NR	1 [8]	4 [33]	NR	NR	3 [25]
	Goksel	62±12	11 [73]	NR	NR	0	4 [27]	2 [13]	0	NR
	Takagi	61±13	28 [72]	33 [85]	2 [5]	3 [8]	NR	3 [8]	6 [15]	NR
	Zoli	58±13	82 [79]	86 [83]	4 [4]	12 [12]	3 [3]	7 [7]	4 [4]	49 [47]
	Mutsuga	55	25 [76]	NR	NR	7 [21]	NR	NR	NR	8 [24]
	Pujara	57±13	139 [82]	157 [93]	40 [24]	27 [16]	53 [31]	11 [7]	16 [9]	120 [71]
	Corvera	60±14	72 [77]	81 [87]	NR	NR	16 [17]	12 [13]	14 [15]	NR
	Nozdrzykowski	61^{M}	10 [67]	15 [100]	2 [13]	2 [13]	2 [13]	0	4 [27]	4 [27]
	Conway	57^{M}	59 [69]	81 [94]	11 [13]	7 [8]	22 [26]	NR	11 [13]	10 [12]
Mean	Historic series	55.4	77.1	NC	NC	NC	NC	NC	NC	NC
	Contemporary series	58.6	71.7	88.8	10.7	13.1	19.8%	8.6	11.8	33.1
	Overall [range]	57.1 [52-62]	76.5 [67-83]	83.9 [74-100]	NC [0-24]	12.0 [0-21]	NC [0-33]	NC [0-13]	11.0 [0-27]	NC [8-71]

^{M}, median; NC, not calculable; NR, not reported.

Table 3 Summary of surgical indication and operative technique

Era	First author	Indication	TAA [%]	Repair technique	CPB time (min)
Historic series	Reul	Aneurysmal growth or sacciform/ symptomatic/massive aneurysm	NR	Resection with interposition graft and false lumen obliteration	NR
	Jex	Symptomatic, aneurysmal growth	NR	Graft interposition	88±7
	Gandjbakhch	Growth of false lumen, malperfusion	10 [83]	Ascending-abdominal aorta bypass (n=7); Ascending-iliac artery bypass (n=3); resection with interposition (n=2)	NR
	Glower	NR	8 [36]	Resection with interposition graft and false lumen obliteration	NR
	Kawashima	NR	15 [54]	Entry closure with aneurysm plication with permanent axillofemoral bypass (n=15); graft interposition (n=13)	NR
	Fann	NR	NR	Graft interposition	83±30
	Safi	NR	NR	Graft interposition	NR
	Okita	>60 mm or rupture	0	Graft replacement with false lumen obliteration	NR
	Zanetti	≥50 mm or symptomatic	5 [25]	Graft interposition	NR
	Miyamoto	NR	18 [45]	Entry closure and aneurysmal wall plication	68±37
Contemporary series	Nienaber	NR	7 [58]	Graft interposition	
	Goksel	Symptomatic or malperfusion or aneurysmal dilation	0	Graft interposition	NR
	Takagi	>55 or >50 mm if Marfan	4 [10]	Graft interposition reinforced with 5cm elephant trunk in distal thoracic aorta or anastomosed to false and true lumen	221±12
	Zoli	Size or rupture or pain or malperfusion	54 [52]	Graft replacement with distal fenestration	NR
	Mutsuga	NR	NR	Entry closure with aneurysm plication (n=8) or graft replacement with aneurysmal vascular tube reimplantation (n=9) or graft replacement alone (n=5)	89
	Pujara	NR	81 [48]	Graft interposition	83^{M}
	Corvera	≥50 mm or growth >10 mm/year or symptomatic or malperfusion	43 [46]	Graft interposition	NR
	Nozdrzykowski	Dilatation or malperfusion or symptomatic or rupture	12 [80]	Graft interposition	144
	Conway	NR	61 [71]	Graft interposition	77^{M}

^{M}, median; NR, not reported. CT, TAA, extension into thoracoabdominal aorta; CPB, cardioplumonary bypass.

Table 4 Summary of clinical outcomes of open surgery for chronic type B aortic dissection

	First author	30-day mortality [%]	Stroke [%]	Spinal cord ischemia [%]	Renal ischemia [%]	Reoperation for bleeding [%]	Late reintervention [%]	Hospital stay (days)
Historic series	Reul	7 [17]	NR	NR	NR	NR	5 [12]	NR
	Jex	5 [14]	1 [3]	1 [3]	5 [14]	5 [14]	NR	NR
	Gandjbakhch	4 [33]	NR	NR	NR	NR	NR	NR
	Glower	2 [9]	NR	NR	NR	NR	5 [23]	NR
	Kawashima	7 [25]	NR	0	3 [11]	NR	NR	NR
	Fann	5 [15]	0	NR	NR	4 [12]	9 [26]	NR
	Safi	9 [10]	8 [9]	NR	NR	NR	NR	NR
	Okita	12 [15]	2 [3]	5 [6]	12 [15]	8 [10]	12 [15]	NR
	Zanetti	3 [15]	NR	1 [5]	3 [15]	NR	NR	NR
	Miyamoto	0	2 [5]	0	0	2 [5]	4 [10]	NR
Contemporary series	Nienaber	1 [8]	3 [25]	2 [17]	3 [25]	NR	NR	40
	Goksel	2 [13]	NR	0	NR	NR	3 [20]	NR
	Takagi	1 [3]	2 [5]	NR	4 [10]	1 [3]	2 [5]	NR
	Zoli	10 [10]	6 [6]	5 [5]	5 [5]	4 [4]	15 [14]	18.3
	Mutsuga	0	2 [6]	3 [9]	1 [3]	2 [6]	NR	NR
	Pujara	14 [8]	8 [5]	4 [2]	18 [11]	23 [14]	23 [14]	11^{M}
	Corvera	2 [2]	1 [1]	3 [3]	1 [1]	4 [4]	8 [9]	NR
	Nozdrzykowski	2 [13]	2 [13]	2 [13]	5 [33]	5 [33]	0	24
	Conway	5 [6]	2 [2]	2 [2]	2 [2]	NR	6 [7]	13.5^{M}
Mean	Historic series	15.2	5.3	4.6	13.5	NC	16.8	NC
	Contemporary series	7.5	5.9	5.1	8.1	8.1	11.3	NC
	Overall [range]	11.1 [0-33]	5.6 [0-13]	4.9 [0-13]	11.9 [0-33]	9.9 [0-33]	13.3 [0-23]	NC

Spinal cord ischemia includes paraplegia or paralysis. Renal ischemia includes renal dysfunction or requiring permanent dialysis; ^{M}, median; NC, not calculable; NR, not reported.

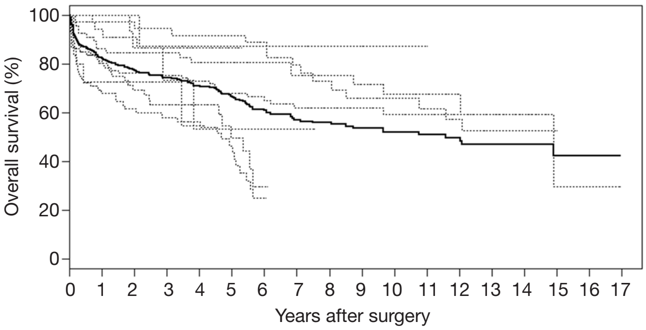

Figure 1 Overall survival based on reconstructed individual patient data. Data of 458 patients from seven studies were reconstructed and presented. Dotted lines represents Kaplan-Meier curves of individual studies, while the solid line represents aggregate reconstructed survival data of the entire cohort.

Discussion

As management of acute aortic dissections improved over the years, there has been an increase in the number of patients with chronic dissections requiring treatment of late complications. Historically, complicated CBAD cases typically necessitated OSR, but since 1999, this has been preferentially supplanted by endovascular approaches. However, despite the lower operative morbidity and mortality of TEVAR, mid-term outcomes are less encouraging, with considerable rates of procedural failure due to endoleaks, persisting false lumen perfusion with aneurysmal dilatation, and need for reintervention (37-39). As such, recent debate has arisen over the current preference of endovascular approaches for the management of CBAD (4).

It is reasonable to expect the short-term procedural outcomes of a minimally invasive endovascular approach to be superior to that of open surgery. In the present series, OSR for CBAD resulted in an average 30-day mortality rate of 11.1% for the entire cohort and 7.5% for patients treated in the contemporary series. The present review also demonstrated that open surgery in the endovascular era carries considerable risks of postoperative strokes (5.9%), spinal cord ischemia (5.1%) and renal ischemia (8.1%). These poor outcomes may be partially attributable to patient selection and the extent of open surgery—48.5% of patients had sufficiently extensive disease to warrant thoracoabdominal repair, with some centers selectively reserving OSR for patients with extensive disease (33).

A key complication of open repair is the risk of spinal cord injuries. While the use of modern perfusion strategies, CSF drainage, active cooling, limitation of spinal cord collateral steal, maintenance of left subclavian artery patency, and close hemodynamic monitoring have improved outcomes, the risk of paraplegia is still not negligible (40). In the present review, 5.1% of patients in contemporary studies experienced some form of spinal cord injury. The identified studies used a variety of spinal cord protection techniques, which demonstrated limited understanding of optimal approach to minimize spinal cord injury.

The recent partiality for endovascular therapies has supplanted OSR as the preferred surgical approach for management of CBADs. As expected, the minimally invasive approach has reported favorable short-term outcomes, with 30-day mortality averaging between 0.8-3.2% in several systematic reviews that examined TEVAR use in chronic type B dissections (37,38,41). However, it must be noted that TEVAR is still a relatively new technique and, in the hands of inexperienced operators (≤20 patients experience), it can still result in mortality rates of up to 8.5% (37). Freedom from reintervention in TEVAR-treated CBAD patients has also been noted to be poor, ranging from 55-80% at 3 years (9,42-44), with reintervention rate of 15.9% (range, 0-60) (38). In a study using Medicare data in the United States of over 15,000 patients undergoing open or endovascular repair for descending thoracic aortic aneurysm, the authors concluded that despite short-term benefits, TEVAR was associated with poorer outcomes in the long-term compared to open surgery, a finding further confirmed with risk-adjusted and propensity-matched cohorts (45). Bearing in mind the limitations of analyzing Medicare data and the different patient sample compared to the present study, these findings nevertheless highlight the uncertainty associated with long-term outcomes of TEVAR treatments. Further investigation, with longer duration of follow-up with imaging, is required to provide greater understanding on this controversial matter.

The rapid advances in the management of chronic type B dissections reflect a growing necessity to conduct further research into this field. The role for OSR for chronic type B dissections needs to be clearly examined, as does patient selection criteria. Optimal timing between symptom onset and intervention must be further investigated, particularly as aortic remodeling is more likely to occur early in the dissection process (46,47). The role of stent-grafting of the descending aorta during open surgery for type A dissections also needs to be determined (48). Cost analysis and quality of life assessment, factors not examined in any of the included studies in this review, must also be better understood. With the formal approval of endoprostheses for use in type B dissections last year by the Food and Drugs Administration in the United States, there will undoubtedly be an upsurge in the use of TEVAR, thus greatly driving the impetus for further research in this field. For patients, the trade-off between the long-term complications of TEVAR, including the risk of endoleaks, further aneurysmal dilation, and the need for ongoing follow-up, must also be carefully considered on a case-by-case basis against the risks of open surgery.

The results of the present review were limited by the heterogeneous nature of the patient cohorts, particularly with respect to indication for surgery and the extent of repair. Direct comparisons to TEVAR should also be made with caution, as TEVAR was typically preferred for those with limited disease and with suitable proximal and distal landing zones, and those considered high risk for open surgery. The lack of higher-level evidence, compounded by heterogenous definitions, surgical techniques, and follow-up protocols, also curtailed robust analysis of the data. Absence of raw patient data meant that long-term survival outcomes could only be estimated using statistical aggregation methods from published Kaplan-Meier graphs. Such techniques assume constant censoring, and also combine what can be a rather heterogenous patient cohort. Finally, while the majority of studies in the present review were performed at centers where there was no endovascular alternative, the preference of TEVAR as the first-line surgical treatment in some centers has relegated open surgery for those with connective tissue or extensive disease, and those unsuitable for endovascular intervention (33,35,49).

In conclusion, OSR for chronic type B dissection remains an important approach for patients. The short-term outcomes of modern open surgery is acceptable, although they appear poorer compared to TEVAR. More research is required to determine long-term benefits of open surgery and TEVAR, as well as the appropriate indications for either approach.

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Supplementary

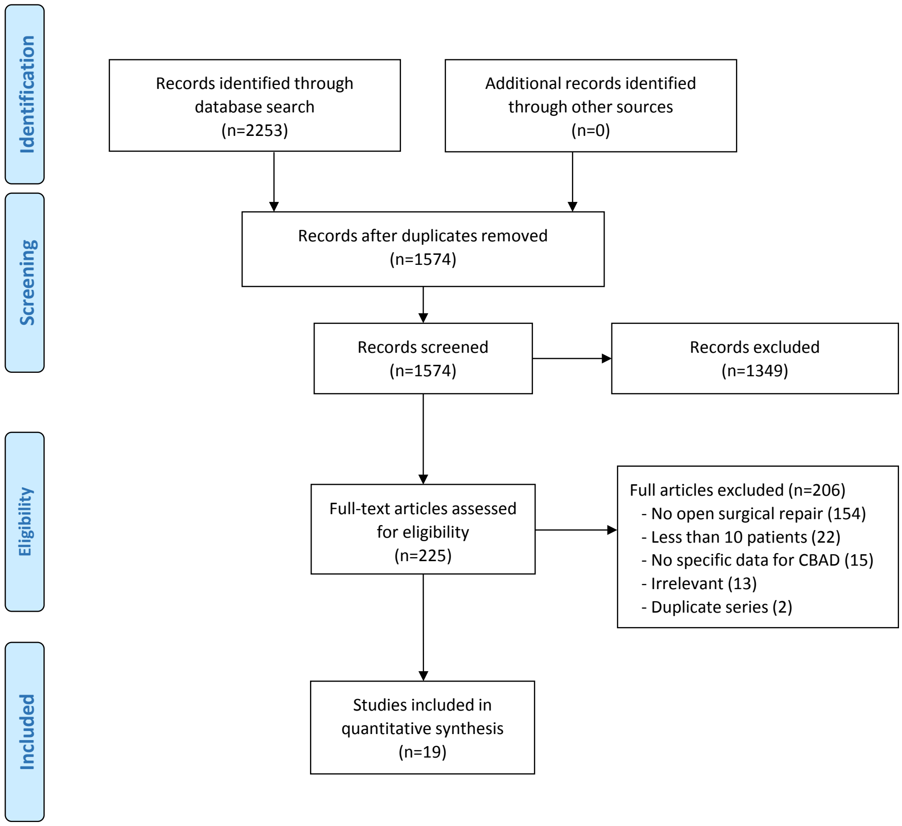

Figure S1 Search strategy of systematic review on open surgical repair for chronic type B aortic dissection. CBAD, chronic type B aortic dissection.

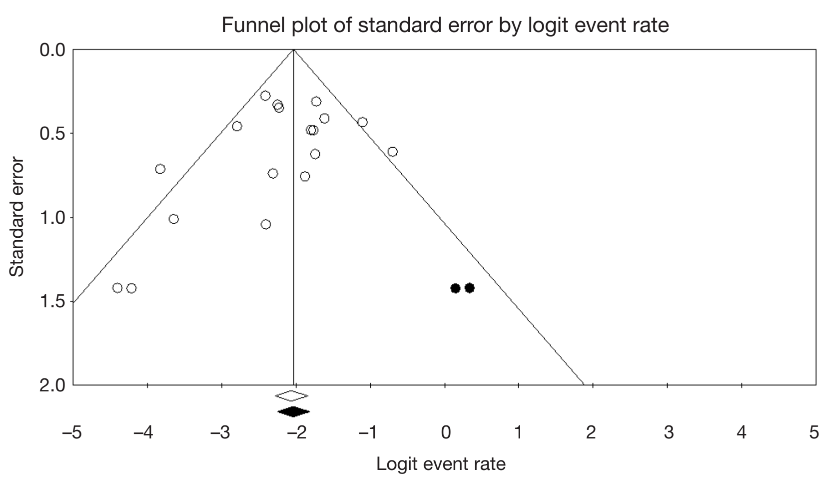

Figure S2 Funnel plot for systematic review of open surgical repair for chronic type B dissection in all 19 included studies. The logit event rate for mortality (horizontal axis) is presented against the standard error (SE) of the log of logit event rate (vertical axis). The SE inversely corresponds to the study size. Asymmetry of the plot can indicate publication bias. Open circles indicate included studies, while the filed circles represent imputed studies identified through Trim and Fill analysis.