A systematic review of endovascular treatment of extensive aortoiliac occlusive disease

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Objectives: **Current multidisciplinary guidelines recommend to treat extensive aortoiliac occlusive disease (AIOD) by surgical revascularization. Surgery provides good long-term patency, but at the cost of substantial perioperative morbidity. Development of new technologies and techniques has led to increased use of endovascular therapy for extensive AIOD. We performed a systematic review of the literature to determine contemporary short- and long-term results of endovascular therapy for extensive AIOD.**

Methods: **The Medline, Embase, and Cochrane databases were searched to identify all studies reporting endovascular treatment of extensive AIOD (TransAtlantic Inter-Society Consensus (TASC) type C and D) from January 2000 to June 2009. Two independent observers selected studies for inclusion, assessed the methodologic quality of the included studies, and performed the data extraction. Outcomes were technical success, clinical success, mortality, complications, long-term primary, and secondary patency rates.**

Results: **Nineteen nonrandomized cohort studies reporting on 1711 patients were included. There was substantial clinical heterogeneity between the studies considering study population and interventional techniques. Technical success was achieved in 86% to 100% of the patients. Clinical symptoms improved in 83% to 100%. Mortality was described in seven studies and ranged from 1.2% to 6.7%. Complications were reported in 3% to 45% of the patients. Most common complications were distal embolization, access site hematomas, pseudoaneurysms, arterial ruptures, and arterial dissections. The majority of complications could be treated using percutaneous or noninvasive techniques. Four- or 5-year primary and secondary patency rates ranged from 60% to 86% and 80% to 98%, respectively.**

Conclusions: **Endovascular treatment of extensive AIOD can be performed successfully by experienced interventionists in selected patients. Although primary patency rates are lower than those reported for surgical revascularization, reinterventions can often be performed percutaneously, with secondary patency comparable to surgical repair. (J Vasc Surg 2010;52:1376-83.)**

Occlusive disease of the aorta and iliac arteries may lead to incapacitating claudication or critical ischemia. Surgical repair in the form of bypass grafting or endarterectomy has proven effective in relieving symptoms and provides good long-term patency. Perioperative morbidity, however, is substantial.[1-4] Endovascular techniques have been developed as a minimal invasive alternative in the treatment of arterial occlusive disease with reduced morbidity compared with surgical repair. In localized or focal aortoiliac occlusive disease (AIOD) endovascular therapy using balloon angioplasty with or without placement of stents currently is the treatment of choice.[5-8]

The TransAtlantic Inter-Society Consensus (TASC) allows classification of AIOD by lesion morphology (Table I).[7,8] According to the multidisciplinary TASC guidelines, published in 2007, endovascular therapy is the preferred method of treatment for localized disease (TASC type A and B), while extensive disease (TASC type C and D) can be best treated by reconstructive surgery.[8] However, recent device developments and increased experience of interventionists have prompted the utilization of endovascular therapy for extensive AIOD. The aim of the present study was to perform a systematic review of contemporary relevant literature on short- and long-term results of endovascular therapy for extensive aortoiliac occlusive disease.

METHODS

A systematic review was performed according to the guidelines of the Meta-analysis Of Observational Studies in Epidemiology group (MOOSE) and the Dutch Cochrane Centre.[9,10]

Search strategy. Two independent investigators (V.J. and K.Y.) performed a computer-assisted search. The medical databases Medline, Embase, and the Cochrane Database of Systematic Reviews were searched (from January 2000 to June 2009), using a combination of the following medical subject headings (MeSH): angioplasty, balloon angioplasty, arterial occlusive diseases, arteriosclerosis, Leriche syndrome, abdominal aorta, and iliac artery. Additionally, a combination of the following free text words was used: endovascular, arterial occlusive disease, occlusive disease, aorta, and iliac artery. Electronic links to related articles and reference lists of selected articles were hand-searched to retrieve more studies. A hand-search for rele-

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Table I. TransAtlantic Inter-Society Consensus (TASC) and Society of Cardiovascular and Interventional Radiology (SCVIR) classifications[8,11]

TASC	*SCVIR*
type A Unilateral or bilateral stenoses of CIA Unilateral or bilateral single short (<3 cm) stenosis of EIA	type 1 Short segment (<2 cm) stenoses of the infrarenal aorta, with minimal atherosclerosis of the aorta otherwise. Iliac stenoses less than 3 cm in length that are concentric and noncalcified.
type B Short (<3 cm) stenosis of infrarenal aorta Unilateral CIA occlusion Single or multiple stenosis totaling 3-10 cm involving the EIA not extending into the CFA Unilateral EIA occlusion not involving the origins of internal iliac or CFA	type 2 2-4 cm stenoses of the infrarenal aorta, with mild atherosclerosis of the aorta otherwise Iliac stenoses 3-5 cm in length or calcified or eccentric stenoses less than 3 cm in length
type C Bilateral CIA occlusions Bilateral EIA stenoses 3-10 cm long not extending into the CFA Unilateral EIA stenosis extending into the CFA Unilateral EIA occlusion that involves the origins of internal iliac and/or CFA Heavily calcified unilateral EIA occlusion with or without involvement of origins of internal iliac and/or CFA	type 3 Long segment (>4 cm) stenoses of the infrarenal aorta Aortic stenosis with atheroembolic disease Medium length (2-4) stenoses of the infrarenal aorta, with moderate to severe atherosclerosis of the aorta otherwise Iliac stenoses 5-10 cm in length
type D Infrarenal aortoiliac occlusion Diffuse disease involving the aorta and both iliac arteries Diffuse multiple stenoses involving the unilateral CIA, EIA, and CFA Unilateral occlusions of both CIA and EIA Bilateral occlusions of EIA Iliac stenoses in patients with AAA requiring treatment and not amendable to endograft placement or other lesions requiring open aortic or iliac surgery	type 4 Iliac stenoses greater than 10 cm in length Chronic iliac occlusions greater than 4 cm in length after thrombolytic therapy Extensive bilateral aortoiliac atherosclerotic disease Aortic or iliac stenoses in patients with AAA or other lesions requiring aortic or iliac surgery

AAA, Abdominal aortic aneurysm; *CFA,* common femoral artery; *CIA,* common iliac artery; *EIA,* external iliac artery.

vant journals and conference proceedings was not performed. A search was not done for unpublished data or abstracts. Relevant studies were selected for full text review based on title and abstract.

Study selection. Studies reporting on endovascular therapy for extensive AIOD were selected based on full text review by two independent authors (V.J. and K.Y.). To be eligible, studies had to report the morphology of aortoiliac occlusive lesions, preferably but not exclusively based upon the TASC guidelines.[7,8] Extensive AIOD was defined as TASC type C or D lesions (Table I). Alternatively, guidelines of the Society of Cardiovascular and Interventional Radiology (SCVIR) could be used for classification of AIOD.[11] SCVIR categories 3 and 4 for iliac artery and aortic angioplasty were considered extensive AIOD (Table I). Studies that did not use TASC or SCVIR classifications could be included only if morphology of aortoiliac occlusive lesions was accurately described, and extensive AIOD could be assumed by both investigators. Studies reporting combined results of localized and extensive AIOD were eligible only if independent results of extensive AIOD could be retrieved or if the majority of the lesions depicted extensive disease. To provide a comprehensive overview all studies reporting on endovascular treatment of extensive AIOD were included, regardless of differences in their methods of intervention (ie, use of percutaneous or open vascular access, use of thrombolysis, or performance of additional surgical outflow procedures). These differences were accounted for during analysis. Only studies published in English or Dutch language were included. Articles had to describe original patient series to be eligible. Studies containing duplicate material were excluded. The larger study, containing the best documented data, was included for analysis. Review articles, technical descriptions, case reports, and small patient series ($N < 10$) were excluded.

Methodologic quality assessment. Two investigators (V.J. and K.Y.) independently assessed the methodologic quality of each included study using a critical review checklist.[9] Study quality was assessed in two ways. First, the fulfillment of seven requirements was determined: a clear definition of the study population, exclusion of selection bias, clear description of method of intervention, detailed description of outcome, data collection by independent or blinded observers, no selective loss of patients to follow-up, and description of confounders. Furthermore, all studies were evaluated using a list of detailed study characteristics as proposed by the MOOSE group.[10] Each item was graded on a scale of 0 to 2 depending on the information available in the article. Quality score was determined by whether the study reported a consecutive series, a prospec-

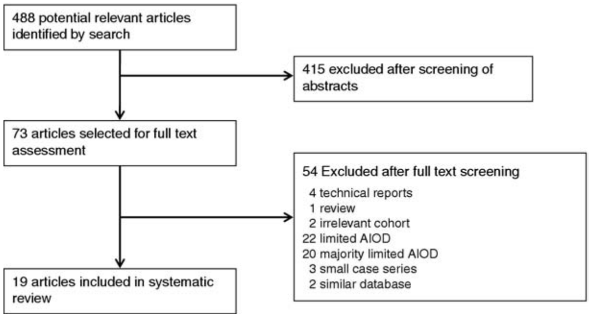

Fig. Flow chart illustrating study selection.

tive series, description of excluded patients and reasons for exclusion, indication for intervention, detailed description of complications, and mortality. Methodologic quality was not an exclusion criterion.

Data extraction. Data were extracted by two authors (V.J. and K.Y.) independently using a standardized form. In case of disagreement, repeat review of the studies in question was performed. If recorded, the following information was extracted from the included studies: publication year, country of origin, number of patients, and study design. In addition, the following data were extracted: patient characteristics, morphology of aortoiliac occlusive lesions, detailed method of intervention, technical success, clinical success, mortality and morbidity rates, and primary, primary-assisted and secondary patency rates. If the study described combined results for limited and extensive AIOD, only data for extensive disease were extracted, if possible.

Any discrepancies in judgment considering search strategy, selection of papers, quality assessment, or data extraction were resolved by discussion between the authors. Final decisions were made after consensus was reached.

RESULTS

The search identified 488 articles of which 73 studies were selected for full text review based on title and abstract. Fifty-four studies were excluded after full text review. Study flow and reasons for exclusion are presented in the Figure. Four technical reports, three small case series and one review article were excluded.[12-19] Two studies reported on similar databases and were excluded.[20,21] Twenty-four studies reported solely on localized AIOD or reported on a different study group and were also excluded. Thirty-one studies reported combined results of localized and extensive AIOD. As specific results for extensive AIOD could not be retrieved from 20 studies, these were excluded. Nineteen studies were included in the systematic review.[22-40] Four studies originated from two study groups but considered different patient groups and were not excluded.[25,31,33,37] The chance adjusted inter-reviewer agreement for study eligibility (κ) was 0.76.

Fifteen studies used TASC classification to describe aortoiliac lesions, while in two studies SCVIR classification was used.[28,38] Two studies did not use a classification system,[32,34] but sufficiently described the morphology of aortoiliac lesions in their patient group to consider them "extensive". In total 1711 patients were evaluated of which 1329 patients had extensive AIOD. From eight studies, specific data on extensive AIOD could be derived,[22,23,25,30,33,35,36,39] while 11 studies reported combined results for extensive and localized AIOD. Three studies specifically reported on aortic occlusive disease.[32-34] Eleven studies were performed in Europe, seven in the United States, and one in Korea.

Study quality. Results of the methodologic quality assessment are presented in Table II. No prospective studies or randomized trials were found. All studies reported results from a single center. In a majority of the studies, selection bias could not be excluded. Patient selection varied between the studies: endovascular treatment of extensive AIOD was performed as treatment of choice,[30,31,36,39] or because patients were unfit for open surgical repair.[22,26,29,32,37] Some studies excluded patients with disease extending into the common femoral artery or aorta,[23,24] while other studies excluded patients with extensive calcified lesions.[30] Also, the use of hybrid techniques (combining surgery with endovascular techniques) varied between the studies. Because of the heterogeneity of the studies, pooling of data was not considered appropriate.

Methods of intervention. Endovascular treatment of extensive AIOD was mostly performed using percutaneous techniques. In two studies, an open technique was used for endovascular access.[22,25] Additional surgical outflow procedures, including endarterectomy of the common femoral artery, femoro-femoral bypass, or femoro-popliteal bypass, were performed in 10 studies.[23,26,27,30,31,34-37,40] In one study, this was performed in a second interventional session.[23] Traditionally, a transfemoral approach was used for endovascular therapy. In some patients, a transbrachial access was used for additional endovascular access.[24,25,30-32,34] Moise et al used the left brachial artery as standard access point in all patients because of the ease of engaging both iliac systems via this route.[33]

To facilitate recanalization and angioplasty or stenting of stenosed or occluded arterial segments intra-arterial thrombolysis was used in selected patients by some authors.[31,33,34,36] Incidentally, debulking of thrombus in case of occlusion or severe long stenoses has been performed using a excimer laser catheter.[23,38] Primary stenting was performed in most studies, while selective placement of stents was performed in four studies only.[27,33,36,39] Indications for stent placement in these studies were occlusions, complex or large plaques, or unsatisfactory technical results after balloon angioplasty alone. Stenting was performed using a variety of bare stents or endografts. In general, balloon-expandable stents were used in heavily calcified lesions, while self-expanding stents were preferred in longer noncalcified lesions.

Outcomes. Outcomes are depicted in Table III. Technical success was reported in all studies and was mostly defined as less then 30% residual diameter stenosis

Table II. Quality assessment of included studies

First author	*Year*	*Study population*	*No selection bias*	*Method of intervention*	*Description of outcomes*	*Independent observers*	*No selective loss to follow-up*	*Description of confounders*	*Quality score of description of study characteristics*
Nyman	2000	+−	+	+	+	−	−	−	7
Scheinert	2001	+−	−	+	+	−	+	+	9
Ali	2003	+	−	+	+	−	+	−	8
Greiner	2003	+−	−	+	+	−	+	−	6
Rzucidlo	2003	+−	+−	+	+	−	+	+	9
Domanin	2005	+−	−	+	+−	−	+	+−	9
Lagana	2006	+−	−	+	+−	−	+	−	8
Ballzer	2006	+	+	+	+	−	+	+	9
De Roeck	2006	+−	−	+	+	−	+	+	9
Park	2007	+−	+	+	+−	−	+	+	7
Piffaretti	2007	+	+−	+	+−	−	+	+	7
Bjorses	2008	+−	+−	+	+	−	+	+	10
Chang	2008	+	−	+	+−	−	+	+	9
Gandini	2008	+−	−	+−	+	−	+	+	9
Hans	2008	+	−	+	+−	−	+	−	8
Sixt	2008	+−	+	+	+	−	+	+	7
Sharafuddin	2008	+−	+−	+	+	−	+	+	7
Kashyap	2008	+−	−	+	+−	−	+	+	6
Moise	2009	+	+	+	+−	−	−	−	8

Quality assessment list of the included studies, depicting whether the articles fulfilled the requirements as stated in the Methods section. + = yes, − = no. A separate quality score was determined based upon the description of study characteristics. Maximum score was 12.

Table III. Summary of data obtained from the included studies

First author	*Year*	*N*	*N eAIOD*	*Age, mean y*	*Male (%)*	*Technical success (%)*	*Clinical improvement (%)*	*Mortality (%) 30 d*	*Morbidity (%)*	*Follow-up, mean mo*	*Length of stay, mean d*
Nyman[a]	2000	30	21	61	43	93	83	6.7	27	19/11[g]	2[median]
Scheinert[a]	2001	212	212[b]	60	78	90	88	0	11	31	4.8
Ali	2003	22	22	63	91	95	100	0	NS	12	NS
Greiner[a]	2003	25	23	NS	60	86	88	0	NS	16	NS
Rzucidlo[a]	2003	34	29	63	62	100	97	3	3	21[max]	NS
Domanin[a]	2005	42	28	60	71	100	100	0	12	NS	NS
Lagana[a]	2006	19	11	66	63	95	NS	0	21	20	3.2
Ballzer	2006	89	89	64	72	97	92	0	16	36	NS
De Roeck[a]	2006	38	26	59	89	97	100	3	5	26	NS
Park	2007	218	66	64[d]	95	98[d]	NS	0	6[d]	30[d]	NS
Piffaretti	2007	43	43	66	70	100	NS	0	5[f]	32	4.1
Bjorses[a]	2008	173	88	64	46	99	86	1.2	14	36	NS
Chang	2008	171	171	67	62	98	92	2.3	22	24[median]	2[median]
Gandini[a]	2008	138	138[c]	63	75	99	99	0	7	108	NS
Hans	2008	40	40	59	60	95	NS	0	15	32	1
Sixt	2008	375	179	63	80	96	70[e]	0	NR	NS	NS
Sharafuddin[a]	2008	66	47	64	70	94	NS	4.5	14	37[median]	NS
Kashyap[a]	2008	83	65	64	57	96	NS	3.6	16	21	NS
Moise	2009	31	31	*65*	29	93	NS	0	45	12	3[median]

N eAIOD, Number of patients with extensive aortoiliac occlusive disease (AIOD); *NR,* data not retrievable for patients with extensive AIOD; *NS,* not stated in the article.
[a]Combined report of limited and extensive AIOD.
[b]SCVIR classification: class III in 46 patients and class IV in 166 patients.
[c]SCVIR classification: class III in 71 patients and class IV in 79 patients.
[d]Combined results of limited and extensive AIOD.
[e]Measured after one year follow-up.
[f]Only major morbidity.
[g]for stenoses and occlusions respectively.

and/or a residual translesion pressure gradient of less than 5 or 10 mm Hg.[22-28,32,35-40] In addition, a marked reduction of the translesion pressure gradient compared with pretreatment values was also considered as technical success by Nyman et al.[34] Reported technical success ranged from 86% to 100%. Most common reasons for technical failure were inability to cross an occluded arterial segment, thrombosis after recanalization, or iliac artery rupture.

Table IV. Primary and secondary patency rates

		1 year		*2 year*		*3 year*		*4 year*		*5 year*	
First author	*Year*	*PP (%)*	*SP (%)*	*PP (%)*	*SP (%)*	*PP (%)*	*SP (%)*	*PP (%)*	*SP (%)*	*PP (%)*	*SP (%)*
Nyman	2000	97	100[a]								
Scheinert	2001	84	88	81	88	78	86	76	85	66	80
Ali	2003			84	95[b]						
Greiner	2003		91[a]		65[a]						
Rzucidlo	2003	70	88								
Domanin	2005	70	88								
Lagana	2006	89	100								
Ballzer	2006					90	96				
De Roeck	2006	94	100	89	94	89	94	77	94	77	94
Park	2007	C 94	C 97			C 94	C 97[a]			C 78	C 74[a]
		D 93	D 94			D 74	D 85[a]			D 74	D 85[a]
Piffaretti	2007	92		86						81	
Bjorses	2008	97	100	88	97	83	95	74	91	65	83
Chang	2008									60	98
Gandini	2008	95	97	93	96	91	94	88	93	86	90
Hans	2008							69	89		
Sixt	2008	C 86	C 98								
		D 85	D 98								
Sharafuddin	2008							81	94[a]		
Kashyap	2008	90	97	82	97	74	95				
Moise	2009	85	100			66	90				

C, Results for patients with TASC type C lesions; *D,* results for patients with TASC type D lesions; *PP,* primary patency; *SP,* secondary patency.
[a]primary assisted patency.
[b]limb salvage rate.

Eleven studies reported clinical outcome directly postintervention or at first follow-up visit. Clinical symptoms improved in 83% to 100% of the patients. In one study, change of clinical symptoms for individual patients was reported only after 1-year follow-up, improvement was recorded in 70% of the patients.[39]

Mortality was reported in all included studies. In 12 studies, no perioperative or 30-day mortality was found, while seven studies reported a mortality rate ranging from 1.2% to 6.7% (Table II). In addition to mortality, morbidity rates could be derived from 16 studies. One study only reported major complications.[36] Reported morbidity rate ranged widely between the other 15 studies (range, 3% to 45%). Most common reported complications were access site hematomas (reported in 7 studies, range, 4% to 17%), distal embolization (reported in 10 studies, range 1% to 11%), arterial dissections (reported in 7 studies, range, 2% to 5%), pseudoaneurysms (reported in 10 studies, range 0.5% to 3%), and iliac artery or aortic ruptures (reported in 7 studies, range 0.5% to 3%). The majority of complications could be treated using percutaneous or noninvasive techniques. Arterial dissections and ruptures were mostly treated by (covered) stent placement, while distal embolization was treated by aspiration or thrombolysis.[24,25,27,28,30,40] Surgical repair was required to treat less then half of the patients with pseudoaneurysms and a few of the patients with access site hematomas or vessel rupture. Length of stay was reported by seven studies and ranged from 1 to 4.8 days.

Patency results are presented in Table IV. One-year primary and secondary patency ranged from 70% to 97% and 88% to100%, respectively. Four- or 5-year primary and secondary patency rates could be derived from eight studies and ranged from 60% to 86% and 80% to 98%, respectively.

Two studies retrospectively compared endovascular therapy and open surgical reconstruction for extensive AIOD.[30,31] Choice of treatment was performed by the surgeon or interventionist treating the patient. Patients who had severe calcifications were not considered for stenting by Hans et al, but no further considerations for treatment allocation were mentioned. Patients undergoing endovascular therapy were older but had similar clinical variables as patients undergoing surgical repair. Mortality did not differ between the groups in both studies, as did morbidity in the study of Kashyap et al. Hans et al reported substantial perioperative morbidity in the open surgery group (pulmonary complications in 13%, cardiac 9%, other systemic complications in 16% and 6% local wound complications).[30] In the endovascular group, intraprocedural complications occurred in 10%, which could all be solved with percutaneous techniques, while two patients experienced access-related complications which could be treated conservatively. Length of stay was measured by Hans et al and was significantly shorter for the endovascular group (1 vs 7 days). Both studies reported significantly lower long-term primary patency for endovascular therapy (69% vs 93%, $P = .013$[30] and 74% vs 93%, $P = .002$ [31]). Secondary patency did not differ significantly, however (89% vs 100%, $P > .05$ [30] and 96% vs 96%[31]).

DISCUSSION

Endovascular therapy currently has been firmly established as the treatment of choice for localized aortoiliac occlusive disease. The role of endovascular techniques in the management of extensive and complex aortoiliac disease, on the other hand, is still controversial. For these patients, the TASC multidisciplinary guidelines recommend operative reconstruction, unless operative risk is prohibitive.[8] Long-term patency rates of aortobifemoral bypass graft or aortoiliac endarterectomy are excellent (85%-92%), with modest operative mortality.[1-4] However, perioperative morbidity of surgical revascularization is substantial, while the time-period before return to normal activities and the effects on sexual function are also important to consider. Systemic or major morbidity rates are reported up to 10%, with overall morbidity 11% to 32%.

Endovascular treatment is a less invasive management option, potentially reducing morbidity. Moreover, when the outcome does not meet expectations, patients may still be referred for conventional surgical therapy without much "lost". The development of new technologies and techniques has led to increasing use of endovascular techniques in the treatment of extensive AIOD. A systematic search revealed 19 clinical studies reporting on endovascular treatment of extensive AIOD. In this heterogenic group of studies, selected patients with extensive AIOD could be treated using endovascular techniques with good technical success rates. Despite the use of various endovascular techniques, technical success was reported over 90% in all but one study.

There was a wide range in reported complication rates. This variation may be caused by varying interventional techniques and different study populations, sometimes with multiple comorbidities. Furthermore, the retrospective nature of the studies may have led to under reporting. Although reported complication rates were considerable, most complications could be treated percutaneously or conservatively. The use of multiple access sites, performance of additional surgical revascularization procedures, and high incidence of comorbidities in most studies may have increased the risk for complications. The high morbidity rate reported by Moise et al (45%) is partly due to access site complications at the brachial artery occurring in 5 of 31 patients.[33] In total, the majority of reported complications were technical, such as iliac artery injury, distal embolization, and access site complications. Growing experience and advances in development of endovascular devices will probably reduce these complications.

Long-term primary patency rates following endovascular treatment cannot yet compete with those reported for open reconstructive surgery. Nevertheless, reinterventions following loss of primary patency after endovascular therapy could be performed using percutaneous techniques in the majority of patients, obtaining secondary patency rates of 80% to 98%. Hereby, the minimal invasive character of the intervention has been maintained, with avoidance of surgery with concomitant risks. It needs to be considered that only one study reported a mean follow-up of more than 5 years.

Several factors that may influence long-term patency after endovascular therapy of AIOD were analyzed in the included studies, including stent placement, lesion morphology, and outflow. The Dutch Iliac Stent Trial, a randomized study comparing primary stenting of AIOD with selective stent placement, has shown similar late patency for both groups, with lower costs in the selective stenting group.[41] Despite this, primary stenting was preferred in most studies for extensive aortoiliac lesions. Arguments in favor of primary stent placements were that stent deployment without predilatation (direct stenting), not only reduces the risk of vessel rupture, but also decreases the risk of distal embolism.[23,30,32,34] Three studies analyzed the influence of stent placement on long-term patency. Neither Domanin et al[27] nor Pifaretti et al[36] found a statistically significant difference in primary patency between patients receiving stent grafting or treated by balloon angioplasty alone. In contrast, Sixt et al[39] found that the 1-year primary patency rate after stenting was significantly better compared to balloon angioplasty alone.

Several studies analyzed the influence of lesion morphology on long-term results. One study found that primary and assisted primary patency rates were significantly lower for iliac artery occlusions over 10 cm in length compared with those for occlusions less than 10 cm in length.[38] On the other hand, none of the other studies found a significant difference between localized vs extensive aortoiliac disease.[24,26,31,35,39,40] Distal outflow may influence primary patency as is pointed out by several authors.[29,30,39] To improve outflow, infrainguinal revascularization was performed in a small majority of the studies.

Aside from endovascular therapy, other alternatives for open surgery are axillobifemoral bypass or (robot-assisted) laparoscopic aortic surgery. Operative morbidity is reduced after axillobifemoral bypass, but durability is also substantially lower.[42,43] Laparoscopic aortic surgery without or with robot-assistance has been developed as a minimal invasive option for AIOD, reducing operative trauma and facilitating quicker ambulation.[44-46] Long-term follow-up results are scarce, however, and more data are required to define the value of (robot-assisted) laparoscopic aortic surgery.

Several limitations to our study need to be addressed. To retrieve recent literature we have restricted our systematic search to studies published after January 2000. Due to this time constriction, relevant studies could have been missed by our search. However, the multidisciplinary TASC guidelines, published in 2007, already considered relevant literature to that date. The aim of this systematic review was to retrieve relevant data not yet considered in TASC guidelines. Furthermore, the majority of the studies included in this review were published in the last 2 years.

The TASC classification for lesion morphology was used by the far majority of studies published on AIOD in the last decade. In some studies, however, other or no classification systems are used. To achieve more studies, those using other or no classification were also included in this review, inevitably leading to increased heterogeneity between the included studies and decreased accuracy for determining extensive AIOD.

Most studies included in this systematic review originate from tertiary referral centers or centers of excellence reporting on selected patients. The results reported by these studies may not be applicable to other centers. In several studies, endovascular therapy was not the primary treatment for extensive AIOD, but offered to patients with significant comorbidities unsuitable for surgical repair. Furthermore, only selected patients suitable for endovascular treatment were reported, while exclusion criteria for endovascular treatment were often not mentioned. All studies were retrospective and most included a small number of patients, precluding adequate subgroup analysis and limiting the value of statistical analysis. Because of these shortcomings, it is difficult to make recommendations regarding technique or patient selection. Despite this, the results from the included studies suggest that most occlusions and long stenoses can be recanalyzed without the need for thrombolysis or laser catheters. Next, in complex lesions, stent placement is mostly preferred over balloon angioplasty alone. Regarding patient selection some authors point out that recanalization of heavy calcified occlusions can be challenging, with a higher risk of vessel rupture during dilatation.[24,25,30] For these lesions, the use of covered stent grafts could prove advantageous.[24,25] However, data from controlled trials is necessary to support these opinions.

The TASC criteria provide a classification system, which can be used to compare outcomes between studies. However, the recommendations of the TransAtlantic Inter-Society Consensus seem in need of reconsideration. Although it is not yet clear if all AIOD lesions are amendable for endovascular therapy, over 1000 patients included in this review have been successfully treated with endovascular techniques, while according to TASC guidelines surgical revascularization should have been the preferred treatment.

In conclusion, endovascular treatment of extensive AIOD can be performed safely and effectively in multiple centers worldwide. In the hands of experienced interventionists, technical success rates are high with modest morbidity. Although primary patency rates of endovascular techniques were inferior to those of open revascularization, reinterventions could often be performed percutaneously. Secondary patency rates are comparable to surgical repair, but length of follow-up after endovascular techniques is still limited. Larger and prospective studies are required to confirm the potential advantages of endovascular treatment over surgery for extensive AIOD. Nevertheless, with continuing developments in endovascular techniques and devices as well as growing experience of interventionalists, indications for endovascular treatment of extensive AIOD will be broadened.

AUTHOR CONTRIBUTIONS

Conception and design: VJ, GA, WW
Analysis and interpretation: VJ, GA, KY, WW
Data collection: VJ, KY
Writing the article: VJ, GA
Critical revision of the article: KY, WW
Final approval of the article: VJ, GA, KY, WW
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