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Endovascular *vs.* Open Repair for Ruptured Abdominal Aortic Aneurysm

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Background: Patients presenting with ruptured abdominal aortic aneurysms are most often treated with open repair despite the fact that endovascular aneurysm repair is a less invasive and widely accepted method with clear benefits for elective aortic aneurysm patients. A debate exists regarding the definitive benefit in endovascular repair for patients with a ruptured abdominal aortic aneurysm. The aim of this literature review was to determine if any trends exist in favor of either open or endovascular repair.

Material/Methods: A literature search was performed using PUBMED, OVID, and Google Scholar databases. The search yielded 64 publications.

Results: Out of 64 publications, 25 were retrospective studies, 12 were population-based, 21 were prospective, 5 were the results of RCTs, and 1 was a case-series. Sixty-one studies reported on early mortality and provided data comparing endovascular repair (rEVAR) and open repair (rOR) for ruptured abdominal aneurysm groups. Twenty-nine of these studies reported that rEVAR has a lower early mortality rate. Late mortality after rEVAR compared to that of rOR was reported in 21 studies for a period of 3 to 60 months. Results of 61.9% of the studies found no difference in late mortality rates between these 2 groups. Thirty-nine publications reported on the incidence of complications. Approximately half of these publications support that the rEVAR group has a lower complication rate and the other half found no difference between the groups. Length of hospital stay has been reported to be shorter for rEVAR in most studies. Blood loss and need for transfusion of either red cells or fresh frozen plasma was consistently lower in the rEVAR group.

Conclusions: Differences between the included publications affect the outcomes. Randomized control trials have not been able to provide clear conclusions. rEVAR can now be considered a safe method of treating rAAA, and is at least equal to the well-established rOR method.

MeSH Keywords: Aneurysm, Ruptured • Aortic Aneurysm, Abdominal • Endovascular Procedures

Full-text PDF: http://www.basic.medscimonit.com/abstract/index/idArt/897601

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Background

Despite advances in operative technique, ruptured abdominal aortic aneurysm (rAAA) remains fatal in the majority of cases and intraoperative mortality remains high in those who survive to undergo repair [1]. In 1994, two vascular teams almost simultaneously introduced an alternative to surgical treatment for rAAA – endovascular aneurysm repair [2,3]. Today, patients presenting with a rAAA are most often treated with open repair (OR) [1]. Endovascular aneurysm repair (EVAR) is less invasive compared to OR and is widely accepted as a method with clear benefits to patients undergoing elective AAA repair [4]. A debate exists regarding the definitive benefit in EVAR for rAAA patients [5,6]. It is expected that modern randomized controlled trials (RCTs) could provide level I evidence and lead to clinical recommendations. Four RCTs are already published regarding this subject.

The aim of this literature review was to compare mortality, complications rates, blood loss, and transfusion needs after EVAR or for rAAA and identify if any trends exist in favor of either method.

Material and Methods

A literature search was performed using PUBMED, OVID, and Google Scholar databases. Text keywords included: endovascular, stent, endograft, stent-graft; open, conventional, surgical; abdominal aortic aneurysm or AAA; and randomized, randomization, adjusted, adjustment, multivariate, multivariable, logistic or regression; and emergency, ruptured or rupture.

Results were filtered for English language and human subjects only. Only those publications comparing rEVAR and rOR were included in the review. Literature search results that did not provide comparative data in any form were excluded [7–9].

The team of authors decided to include data from publications that did not clearly state the comparative nature of their results only if this data could be retrieved from the manuscripts.

Data on symptomatic AAAs (sAAAs) were filtered out, as sAAA is not a synonym for rAAA and the term includes peripheral embolism and painful non-ruptured aneurysms.

The final short-list comprised 64 publications. Some publications failed to mention the statistical significance of their results, but these were included in our review and are distinguished by specifying the lack of *p* values. In these cases, conclusions of the respective authors should be read and accepted with caution and treated as evidence level 4 or 5. The team of authors used these publications only to identify existing trends.

Results

Out of 64 publications, 25 (39%) were retrospective studies, 12 (18.8%) were population-based, 21 (32.8%) were prospective, 5 (7.8%) were the results of RCTs (with 2 publications coming from the same RCT), and 1 (1.6%) was a case-series.

Sixty-one studies report on early mortality and provide comparative data between the rEVAR and rOR groups (Table 1). Twenty-nine of these studies support that rEVAR presented with a lower early mortality rate, but only 22 report the statistical significance of the respective results. The rest of the studies, including 4 RCTs, conclude that there is no difference in early mortality between the 2 groups. Almost all the population-based studies demonstrated a lower early mortality rate after rEVAR; therefore, results in favor of rEVAR come from a larger population sample; 15 125 (10%) patients underwent rEVAR out of 147 426 patients in total. There is only 1 population-based study in favor of rOR; therefore, the population sample size of all the studies supporting lower early mortality in the rOR group is significantly smaller (a sample of 10 695 patients in total. Only 3 studies supporting similar early mortality between rOR and rEVAR did not provide the statistical significance of their results.

Late mortality after rEVAR compared to that of rOR was reported in 21 manuscripts (Table 2). Authors report their respective results for periods ranging from 3 to 60 months. Results from 13 studies (61.9%) show no difference in late mortality rates between the rEVAR and the rOR groups, with 3 RCTs being among these studies. Seven studies (33.3%) report lower late mortality rates for the rEVAR group, including 2 population-based studies and 1 prospective intention-to-treat (ITT) study. Only 1 study (4.8%) reported a higher late mortality rate in the rEVAR group, but if early data is excluded (prior to 2005), the respective late mortality rates do not differ between the rEVAR and the rOR groups (p=.57).

Thirty-nine publications report on the complication incidence, most in a narrative way, with only 12 publications reporting their complication rates with statistical significance (Table 3). Twenty of these publications support that the rEVAR group has a lower complication rate and 18 report no difference between the rEVAR and the rOR groups. One study concluded that the rEVAR group had a higher incidence of complications, but no *p* value was reported [10]. Data regarding complications are extremely heterogeneous in methods of recording, grouping, and reporting the complications.

Length of hospital stay (LOS) was reported to be shorter for the rEVAR group in 20 studies, despite 9 of them not stating whether this result is statistically significant. One RCT (IMPROVE) supported that LOS is shorter for the rEVAR group. Twenty-one

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Table 1. Early mortality results.

First Author	Year	Type of study	Number of patients	% treated with rEVAR	Early mortality (endo % *vs.* open %; p value)
Ohki [36]	2000	Retrospective	25	80.0%	No difference (10% *vs.* 0%; NS)
Hinchcliffe [37]	2001	RCT (Nottingham trial)	32	49.0%	No difference (53% *vs.* 53%)
Yilmaz [38]	2002	Prospective/ Retrospective	64	37.5%	No difference (24% *vs.* 41%; NS)
Peppelenbosch [10]	2003	Prospective/ Retrospective	40	65.0%	No difference (31% *vs.* 50%; NS)
Resch [39]	2003	Prospective/ Retrospective	37	37.8%	No difference (29% *vs.* 35%; p>.05)
Reichart [40]	2003	Prospective/ Retrospective	26	23.1%	N/A
Lee [41]	2004	Retrospective	36	36.0%	Lower in rEVAR (7.7% *vs.* 30.8%)
Alsac [26]	2005	Case series	37	46.0%	Lower in rEVAR (23.5% *vs.* 50%; p=.09)
Kapma [42]	2005	Prospective	253	15.8%	Lower in EVAR (13% *vs.* open 30%; p=.021)
Larzon [28]	2005	Prospective	50	30.0%	No difference (13% *vs.* 46%; p>.05)
Castelli [27]	2005	Retrospective	46	54.3%	No difference (20% *vs.* 47.6%; NS)
Vaddenini [43]	2005	Retrospective	24	62,5%	No difference (22% *vs.*. 26%)
Brandt [44]	2005	Retrospective	39	54.0%	Lower in rEVAR (8% *vs.* 53%, P=.003)
Peppelenbosch [45]	2006	Prospective; Multicentre (ERA trial)	100	49.0%	No difference (35% *vs.* 39%; p=.78)
Greco [35]	2006	Population-based	5798	3.4%	N/A
Visser [46]	2006	Prospective	55	47.3%	No difference (31% *vs.* 31%; p=.98)
Arya [47]	2006	Prospective ITT	51	33.3%	No difference (24% *vs.* 47%; p=.14)
Franks [48]	2006	Retrospective	19	47.3%	No difference (11% *vs.* 54%; p=.03)
Coppi [49]	2006	Retrospective	124	26.6%	No difference (30% *vs.* 46%)
van der Viet [50]	2007	Prospective	77	64.0%	Lower in EVAR (25% *vs.* 49%; p=.04)
Moore [51]	2007	Prospective; Protocol modified	126	15.9%	Lower in rEVAR (5% *vs.* 28%, p=.0084)
Najjar [52]	2007	Retrospective	37	40.5%	No difference (6.7% *vs.* 13.6; p=.61)
Ockert [53]	2007	Retrospective	58	50.0%	No difference (31% *vs.* 31%; p=1.0)
Sharif [54]	2007	Retrospective	126	58.7%	Lower in EVAR (32.7% *vs.* 51.4%; p=.05)
Acosta [55]	2007	Retrospective	162	34.6%	No difference (34% *vs.* 45% in-hospital mortality; p=.16)
Anain [56]	2007	Retrospective	40	75.0%	No difference (17% *vs.* 40%; p=.19)
Dalainas [57]	2008	Prospective	28	71.4%	No difference (40% *vs.* 62.6%; p>.05)
Egorova [34]	2008	Population-based	43033	2.5%	Lower in rEVAR up to 90 days postop
Lesperance [58]	2008	Population-based	9931	9.6%	Lower in rEVAR (31% *vs.* 42%; p<.001)
Lee [59]	2008	Prospective	37	45.9%	Lower in EVAR (35% *vs.* 75%; p=.02)
Wibmer [30]	2008	Retrospective	47	34.0%	No difference (0% *vs.* 12.9%; p=.28)
Giles [60]	2009	Population-based	567	21.0%	Lower in rEVAR (24% *vs.* 36%; p<.05)
Giles [61]	2009	Population-based	28429	8.2%	Lower in rEVAR (33% *vs.* 41%; p<.001)

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Table 1 continued. Early mortality results.

First Author	Year	Type of study	Number of patients	% treated with rEVAR	Early mortality (endo % *vs.* open %; p value)
McPhee [62]	2009	Population-based	27750	11.5%	Lower in rEVAR (31.7% *vs.* 40.7%; p <.0001)
Vogel [63]	2009	Population-based	5176	12.0%	No difference (45.1% *vs.* 52.4%; p=.21)
Verhoeven [64]	2009	Prospective	159	71.7%	Lower in EVAR (20% *vs.* 27.2%)
Visser [65]	2009	Prospective; Multicentre	201	28.9%	No difference (26% *vs.* 40%; p=.06)
Vun [66]	2009	Retrospective	45	15.6%	Lower in EVAR (0% *vs.* 42%)
Veith [67]	2009	Retrospective	1443	47.1%	Lower in EVAR (17.4±8.9% *vs.* 35.8±12.4%; p=.0001)
Holt [68]	2010	Population-based	4414	7.6%	Lower in EVAR (32.2% *vs.* 47.4%; p<.001)
Lyons [69]	2010	Retrospective	47	38.0%	No difference (11% *vs.* 32%; NS)
Starnes [70]	2010	Retrospective	46	48.0%	Lower in EVAR (18.5% *vs.* 54.2%; p=.01)
Chagpar [71]	2010	Retrospective	167	19.2%	Lower in rEVAR (15.6% *vs.* 43.7%; p=.004)
Van Schaik [72]	2011	Prospective	56	26.8%	Lower in EVAR (26% *vs.* 46%)
Sarac [73]	2011	Retrospective	160	32.0%	No difference (31.2% *vs.*. 32%; p=.93)
Ten Bosch [74]	2012	Prospective	129	19.0%	Lower in EVAR (20% *vs.* 45%; p=.021)
Mayer [75]	2012	Prospective ITT; Multicentre	473	57.0%	Lower in rEVAR (15.7% *vs.*. 37.4%; p=0.35)
Ioannidis [76]	2012	Retrospective	43	46.5%	No difference (35% *vs.* 43%; p=.627)
Nedeau [77]	2012	Retrospective	74	25.7%	Lower in rEVAR (15.7% *vs.* 49%; p=.008)
Noorani [78]	2012	Retrospective	102	51.0%	Lower in rEVAR (12% *vs.* 28%)
Saqib [25]	2012	Retrospective	278	13.3%	No difference (50% *vs.* 54%; p=.66)
Park [79]	2013	Population-based	16558	22.9%	Lower in rEVAR (OR=0.492; CI, 0.380–0.636)
Mehta [80]	2013	Prospective ITT	283	42.4%	Lower in rEVAR (24.2% *vs.* 44.2%; p<.005)
Reimerink [81]	2013	RCT (AJAX trial)	116	49.1%	No difference (21% *vs.* 25%; p=.66)
Wu [82]	2014	Retrospective	36	42.9%	No difference (33.3% *vs.* 15.5%; p=.201)
Mohan [83]	2014	Population-based	41,126	19.3%	Lower in EVAR (25.9% *vs.*. 39.1%; p<0.001)
Speicher [84]	2014	Population-based	1997	30.7%	Lower in EVAR (26.2% *vs.* 38.5%; p<.001)
Edwards [85]	2014	Prospective	10998	10.0%	Lower in rEVAR (38.8 *vs.* 47.7%)
van Beek [16]	2015	Observational based on AJAX trial	467	15.6%	N/A
Gunnarsson [22]	2015	Population-based	1304	26.0%	No difference (28% *vs.* 27.4%; p=.87)
McHugh [4]	2015	Prospective	41	56.0%	No difference (34.8% *vs.* 38.9%; p=.786)
Desgranges [86]	2015	RCT (ECAR trial)	107	52.3%	No difference (39.3% *vs.* 41%; p=.239)
Improve Trial Investigators [23]	2015	RCT (IMPROVE trial)	613	51.5%	No difference (35.4% *vs.* 37.4%; p=.62)
Huang [19]	2015	Retrospective	1534	58.0%	No difference (0.9% *vs.* 1.3%; p=.56)

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Table 2. Late mortality results.

First Author	Late mortality	Follow-up period (months)	p value
Huang [19]	Higher in rEVAR	60	<.001; No difference for patients operated after 2005 (p=.57)
Ten Bosch [74]	Lower in EVAR	N/A	<0.14
Edwards [85]	Lower in rEVAR	>48	N/A
Noorani [78]	Lower in rEVAR	24	N/A
Mehta [87]	Lower in rEVAR	N/A	<.005
Greco [35]	Lower in rEVAR	48	.005
Nedeau [77]	Lower in rEVAR	20	N/A
Egorova [34]	Lower in rEVAR	N/A	.004
Visser [29]	No difference	N/A	.19
Reichart [40]	No difference	6	NS
Ockert [53]	No difference	Mean 40.25	.41
Lyons [69]	No difference	6	NS
Wibmer [30]	No difference	3	1.0
Reimerink [81]	No difference	6	.84
van Beek [24]	No difference	N/A	.83
Gunnarsson [22]	No difference	12 & 24	.19 @ 1 year,.28 @ 2 years
Peppelenbosch [45]	No difference	3	.56
Improve Trial Investigators [23]	No difference	12	.325
Saqib [25]	No difference	N/A	.66
Wu [82]	No difference	N/A	.093
Desgranges [86]	No difference	12	.296
Sarac [73]	No difference	N/A	.24

publications report on intensive care unit length of stay (ICU-LOS) (Table 4). Six of these studies report that there is no difference in ICU-LOS between patients who have undergone rEVAR or rOR, with only 1 study failing to report a *p* value. Fifteen publications showed that ICU-LOS was shorter in the rEVAR group, with 3 of them not reporting a *p* value to support their results.

Blood loss and need for transfusion of either red cells (RC) or fresh frozen plasma (FFP) was consistently lower in the rEVAR group, as suggested by the results of 22 publications (Table 4), including results of 2 RCTs – AJAX and ECAR. Two studies reported that there is no difference between the transfusion needs of patients undergoing either rEVAR or rOR, but with only a marginal statistical significance (p=.07). One study showed no difference between the 2 groups regarding FFP transfusions, but RC needs were lower in the rEVAR group.

Discussion

Despite the widespread use of EVAR as a safe and, in some cases, superior method to OR for elective AAA repair, its role in rAAA repair remains controversial due to the absence of well-supported evidence. Published RCTs to date have not succeeded in clarifying what the criterion standard for rAAA repair should be.

Benefits of rEVAR regarding early mortality (30-day or in-hospital) remain ambiguous, as approximately half of the published studies report a lower early mortality in the rEVAR group, while the other half support that there is no significant difference between the rEVAR and the rOR groups in early mortality. To confound matters further, all 4 published RCTs support a lack of difference between the 2 groups in terms

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Table 3. Incidence of complications.

First Authors	Complications	p value
Peppelenbosch [10]	Higher in rEVAR groups	N/A
Peppelenbosch [45]	Lower in rEVAR group	≤.02 (No difference @ 3 months)
Brahmbhatt [88]	Lower in rEVAR group	<.001
Resch [39]	Lower in rEVAR group	N/A
Alsac [26]	Lower in rEVAR group	N/A
Castelli [27]	Lower in rEVAR group	N/A
Brandt [44]	Lower in rEVAR group	N/A
Dalainas [57]	Lower in rEVAR group	N/A
Lesperance [58]	Lower in rEVAR group	N/A
Giles [60]	Lower in rEVAR group	N/A
McPhee [62]	Lower in rEVAR group	N/A
Van Schaik [72]	Lower in rEVAR group	N/A
Nedeau [77]	Lower in rEVAR group	N/A
Gunnarsson [22]	Lower in rEVAR group	N/A
Desgranges [86]	Lower in rEVAR group	N/A
Improve Trial Investigators [23]	Lower in rEVAR group	N/A
Huang [19]	Lower in rEVAR group	N/A
Noorani [78]	Lower in rEVAR group	<.001
Giles [89]	Lower in rEVAR group	<.01
Speicher [84]	Lower in rEVAR group	<.001
Park [79]	Lower in rEVAR group	OR=0.535; CI, 0.395-0.724
Ohki [36]	Lower in rEVAR group	N/A
van Beek [24]	No difference	N/A
Greco [35]	Lower in rEVAR group (regarding systemic complications; no difference in postoperative method-related complications)	N/A
Arya [47]	No difference	N/A
Hinchcliffe [37]	No difference	N/A
Anain [56]	No difference	N/A
Saqib [25]	No difference	N/A
Wu [82]	No difference	N/A
Larzon [28]	No difference	N/A
Franks [48]	No difference	.28
Ockert [53]	No difference	.9
Coppi [49]	No difference	N/A
Reimerink [81]	No difference	.56 @ 30 days;.71 @ 6 months
Vaddenini [43]	No difference	N/A
Lee [41]	No difference	.26
Visser [29]	No difference	.40 in-hospital;.36 @ 1 year
Wibmer [30]	No difference	N/A
Lyons [69]	No difference	NS

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Table 4. Length of Stay (LOS), Intensive care unit LOS (ICU-LOS), blood loss, and need for transfusion.

First Author	Length of stay	Intensive Care Unit	Blood loss ± need for transfusion (p value)
Ohki [36]	Shorter in rEVAR	N/A	Lower in rEVAR (N/A)
Lee [41]	Shorter in rEVAR (p<.05)	N/A	Lower in rEVAR (<.0001)
Najjar [52]	Shorter in rEVAR (p<.05)	N/A	Lower in rEVAR (<.05)
Lesperance [58]	Shorter in rEVAR (p<.001)	N/A	N/A
Giles [89]	Shorter in rEVAR (p<.0001)	N/A	N/A
Giles [61]	Shorter in rEVAR (p<.0001)	N/A	N/A
McPhee [62]	Shorter in rEVAR (p<.0001)	N/A	N/A
Starnes [70]	Shorter in rEVAR (p<.037)	N/A	Lower in rEVAR (<.001)
Saqib [25]	No difference (p=.13)	N/A	Lower in rEVAR (p<.02 for RC & p=.0001 for FFP)
Nedeau [77]	Shorter in rEVAR (p=.004)	N/A	Lower in rEVAR (<.00005)
Park [79]	Shorter in rEVAR (p<.0001)	N/A	N/A
Reimerink [81]	N/A	N/A	Lower in rEVAR (<.001)
Mehta [80]	N/A	N/A	Lower in rEVAR (<.005)
Speicher [84]	Shorter in rEVAR (p<.001)	N/A	N/A
Edwards [85]	Shorter in rEVAR (p<.001)	N/A	N/A
Mohan [83]	Shorter in rEVAR (p<.01)	N/A	N/A
Improve Trial Investigators [23]	Shorter in rEVAR (p<.001)	N/A	N/A
Vogel [63]	No difference (p=.8)	No difference	N/A
Gunnarsson [22]	N/A	No difference (p=.23) for pts staying in ICU >5 days	N/A
Reimerink [81]	No difference (p=.57)	No difference (p=.24)	N/A
McHugh [4]	No difference (p=.61)	No difference (p=.538)	N/A
Wu [82]	No difference (p=.672)	No difference (p=.597)	Lower RC transfusion in EVAR group (p<.03); No difference in other blood products
Ockert [53]	No difference (p=.69)	No difference (p=.98)	N/A
Peppelenbosch [10]	Shorter in rEVAR	Shorter in rEVAR	Lower in rEVAR (<.001)
Reichart [40]	Shorter in rEVAR	Shorter in rEVAR	Lower in rEVAR (N/A)
Huang [19]	Shorter in rEVAR (p<.001)	Shorter in rEVAR (p<.001)	N/A
Kapma [42]	Shorter in rEVAR (p<.001)	Shorter in rEVAR (p<.001)	Lower in rEVAR (<.001)
Vaddineni [43]	N/A	N/A	Lower in rEVAR (<.0001)
Franks [48]	Shorter in rEVAR (p<.001)	Shorter in rEVAR (p<.002)	Lower in rEVAR (<.001)
Alsac [26]	No difference (p=.69)	Shorter in rEVAR (p<.01)	Lower in rEVAR (<.01)

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Table 4 continued. Length of Stay (LOS), Intensive care unit LOS (ICU-LOS), blood loss, and need for transfusion.

First Author	Length of stay	Intensive Care Unit	Blood loss ± need for transfusion (p value)
Peppelenbosch [10]	No difference	Shorter in rEVAR (p<.019)	Lower in rEVAR (<.01)
Ioannidis [76]	N/A	Shorter in rEVAR (p<.042)	Lower in rEVAR (<.001)
Arya [47]	No difference (p=.83)	Shorter in rEVAR (p=.01)	No difference (.07)
Visser [29]	Shorter in rEVAR (p=.003)	Shorter in rEVAR (p=.01)	Lower in rEVAR (<.001)
Desgranges [86]	No difference (p=.208)	Shorter in rEVAR (p=.012)	Lower in rEVAR (<.02)
Resch [39]	N/A	Shorter in rEVAR (p=.02)	Lower in rEVAR (p=.0001 & p=.02 for blood loss & transfusion, respectively)
Wibmer [30]	No difference (p=.74)	Shorter in rEVAR (p=.02)	No difference (.62)
Anain [56]	No difference (p=.149)	Shorter in rEVAR (p=.046)	Lower in rEVAR (<.008)
Lyons [69]	No difference (p=NS)	Shorter ITU stay in EVAR group (p=.05)	Lower in rEVAR (<.05)
Vun [66]	N/A	N/A	Lower in rEVAR (p<.0006 for RC & p=.03 for FFP)

of early mortality. Antoniou et al. recently published a meta-analysis including 3 out of 4 available RCTs, which reported lower early mortality with rEVAR; their findings are supported by other publications [11–15]. Another meta-analysis, by van Beek et al., which included the 3 above-mentioned RCTs and a number of other studies, reported that rEVAR is not inferior to rOR and should be considered an accepted repair method for rAAA [16]. Badger et al. also reported non-inferiority of rEVAR compared to rOR, a finding supported by Sweeting et al. in their meta-analysis [17,18]. Despite the fact that many studies report that there is no significant difference in early mortality between the rEVAR and the rOR groups, a clear trend exists in favor of rEVAR. This trend appears only when mortality rates, expressed in percentages as rates for rEVAR, are consistently lower than the ones for rOR.

This trend has to be studied further to be accepted as scientifically valid, but it cannot be dismissed out of hand. On the basis of all of the above, rEVAR should be considered at least equal to rOR in terms of early mortality and is an acceptable method of rAAA repair.

In terms of late mortality, the data provided is rather heterogeneous, as authors used different periods of time to report on late mortality. In the 22 publications included in our review, these periods vary widely, from 3 to 60 months. Approximately two-thirds of publications report that there is no difference between rEVAR and rOR groups for late mortality. Seven publications report that rEVAR group has a lower late mortality incidence and these results are statistically significant. The retrospective study by Huang et al. showed higher rEVAR late mortality for patients who had undergone a repair between 2000 and 2005 (p<.001), but there was no difference in late mortality between rEVAR and rOR patients who had undergone a repair after 2005 (p=.57) [19]. These findings could be explained by the use of improved devices in the latter years of the study (2005–2011), but also by the experience vascular surgeons have acquired over time. Since endovascular devices have changed and skills have improved, data acquired over longer periods of time should probably not be pooled together. Data on late mortality from the publications included in this review seem to support that rEVAR is equal to rOR, but a rEVAR superiority trend could still be identified, as mentioned by Sweeting et al. in their recent meta-analysis [20].

Many complications can occur during or after rAAA; some are modality-specific, such as the occurrence of endoleaks after rEVAR, while other complications are common to both repair methods, and can be *systemic* (blood loss, myocardial infarction, multi-organ failure, renal injury, abdominal compartment syndrome) or *local* (wound infection, hematoma). Abdominal compartment syndrome (ACS) is a life-threatening complication [21] that is often underdiagnosed; its reported prevalence is between 20% and 25% [5]. In this review, only 3 papers concluded that rEVAR had significantly higher incidence of ACS than rOR [22–24]. One paper reports no difference between the rOR and rEVAR groups regarding ACS [25]. Five more papers describe single cases of ACS without any comparative data [26–30]. Publications that present data on incidence of complications and are included in this review use

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different methods of recording, grouping, and reporting these complications. These differences make it difficult to perform a meta-analysis of the data and therefore can be listed only for reference purposes without the ability to draw a general conclusion (Table 3). Most publications tend to support that the incidence of complications is lower in the rEVAR group, but some of them either fail to report whether the respective results are statistically significant, or draw different conclusions for each complication without statistical analysis of pooled complication incidence.

Two-thirds of publications support that hospital length of stay (LOS) is shorter in the rEVAR group, with 1 RCT included in these publications (IMPROVE). On the other hand, the rest of the publications, including 2 RCTs (AJAX and ECAR), support that there is no statistically significant difference in LOS between the rEVAR and the rOR groups. The ICU-LOS was shorter in the rEVAR group according to most publications. Results from 2 RCTs seem contradict each other, with the ECAR results supporting shorter ICU-LOS in the rEVAR group and AJAX results finding no significant difference in the ICU-LOS of rEVAR compared to rOR. The only meta-analysis regarding LOS in rAAA repair, recently published by Thomas et al., support significantly shorter LOS in the rEVAR group [15].

In most publications, the rEVAR group consistently presented with less blood loss and lower need of red cells (RC) and fresh frozen plasma (FFP) transfusions. Less blood loss and lower need for transfusions can be considered a clear advantage of rEVAR and because enough evidence exists to support this advantage, it can safely be taken under clinical consideration.

Further considerations demonstrate the heterogeneity of the studies included in this review. One major difference is the type of endograft used in the rEVAR procedures, with some centers using aortouniliac endografts combined with an open femoro-femoral bypass, while other centers used bifurcated or tube grafts. Outcomes from these 2 different approaches to rEVAR may in some aspects vary [31]. Furthermore, endografts of a similar kind (tube, bifurcated, or aorto-uniliac) differ in the manufacturing method and the materials used, a factor that has been found to play a role in some of the outcomes [32].

Hostile aortic anatomy has been an exclusion criterion in the included publications, as rEVAR should ideally follow the indications-for-use (IFUs) of the endograft chosen. This is a bias of all the literature we have reviewed, but not one that can be circumvented. Since anatomic suitability is essential for rEVAR, patients with hostile aortic anatomy tend to be treated using rOR [6]. Another patient-related variable is their hemodynamic state at presentation. Some centers are reluctant to treat unstable rAAA patients with rEVAR because a CT-angiography (CTA) is necessary for pre-operative planning, which is a diagnostic examination that requires a period of time. In most centers, the time necessary to complete a CTA does not influence mortality, and a study has reported that rEVAR in unstable patients has lower early mortality compared to rOR [33].

Center-related characteristics are also reported to have an impact on the rEVAR results. A number of studies have demonstrated that high-volume centers performing rEVAR show lower mortality and better overall results than the centers with lower volumes of patients [33–35].

Conclusions

Publications comparing rEVAR to rOR have similar primary endpoints, such as early and/or late mortality and incidence of complications. Some include secondary endpoints, such as LOS, ICU-LOS, operative time, blood loss, and transfusion needs. The differences between the publications lie in the design of the respective study, the study duration, the type of endografts used, volume of patients each study center enrolled, and many other characteristics, each affecting the overall outcome. RCTs have not been able to provide clear conclusions apart from that rEVAR is not inferior to rOR regarding mortality and complications. For now, one of the points on which the existing literature seems to agree upon is the reduced blood loss and the less frequent need for transfusion in patients undergoing rEVAR. The other and most significant point is that rEVAR can now be considered a safe method of treating rAAA, being at least equal to the well-established rOR. Further studies are necessary to clarify the advantages and disadvantages of each repair method and the sub-groups of patients who will benefit the most from each method.

Conflict of Interest

None.

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