Mortality After Endovascular Repair of Ruptured Abdominal Aortic Aneurysms

A Systematic Review and Meta-analysis

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Objective: To document mortality after endovascular repair of ruptured abdominal aortic aneurysms (RAAAs).

Data Sources: MEDLINE and EMBASE databases.

Study Selection: Articles that reported data on mortality after endovascular repair of RAAAs were identified. Only patients with true ruptures were included. Additionally, information on mortality after concurrent open repair was sought.

Data Extraction: One of the authors reviewed all of the studies and extracted appropriate data. A total of 43 articles were identified, 14 of which were excluded.

Data Synthesis: Twenty-nine articles with 897 patients who underwent endovascular repair met the inclusion criteria. Of the patients with available information, 86% were men; 29% had been operated on under local anesthesia; 28% were hemodynamically unstable; 17% required intra-aortic balloon occlusion; 48% received bifurcated stent grafts; 6% had endovascular procedures converted to open repair intraoperatively; and 5.5% developed abdominal compartment syndrome. In-hospital and/or 30-day mortality ranged between 0% and 54% in different series, whereas the pooled mortality after endovascular repair was 24.5% (95% confidence interval [CI], 19.8%-29.4%). In 19 studies reporting results of both endovascular and concurrent open repair from the same unit, the pooled mortality after open repair was 44.4% (95% CI, 40.0%-48.8%), and the pooled overall mortality for RAAA undergoing endovascular or open repair was 35% (95% CI, 30%-41%).

Conclusions: Endovascular repair of RAAAs is associated with acceptable mortality rates. Additional studies will be required to verify these promising results and precisely define the role of endovascular treatment as an additional therapeutic option for RAAAs.

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Despite the advances made in modern practice, the mortality rate of open surgical treatment of ruptured abdominal aortic aneurysms (RAAAs) persists in the 50% range.[1-3] The overall risk of death from RAAAs is even higher, approaching 80% to 90%, as less than half of the patients reach the hospital alive.[4] A recent meta-analysis of 50 years of RAAA repairs did show a gradual reduction in perioperative mortality; however, this gradual improvement may reflect reporting bias and patient selection.[5] Most of the recent literature on RAAAs has focused on endovascular repair.[6-52] Endovascular techniques, increasingly used for elective AAAs, could offer an attractive option in rupture cases because of their reduced physiological stress. Several centers performing endovascular repair have published data on endovascular treatment of RAAAs, but most of these articles are reports of single-center experiences with a small number of patients. Some of the results are promising, though the reported mortality figures vary widely. Therefore, there is uncertainty with regard to whether the outcome of such patients can be improved by endovascular surgery. The aim of this study was to estimate the operative mortality of endovascular treatment of RAAAs by performing a systematic review of the relevant literature.

See Invited Critique at end of article

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METHODS

An English-language literature review of articles published through December 2006 was undertaken to define the role of endovascular management of RAAAs. This article was prepared according to previously published guidelines for meta-analyses of observational studies.[53]

STUDY SEARCH

The lead author (C.D.K.) performed the literature search using the Ovid search engine (version 10.5.1; Ovid Technologies Inc, New York, New York). Both the MEDLINE (January 1966-December 2006) and EMBASE (January 1980-December 2006) databases were searched using a combination of the following terms: *endovascular surgery*, *endovascular repair*, *stents*, or *stent grafts*; *abdominal aortic aneurysm* or *aortic aneurysm*; and *abdominal* and *rupture*, *aortic rupture*, or *aneurysm rupture*. Both the "exp" ("Explode," ie, all subcategorizations are included in the search) and "mp" ("Multipurpose Search") tools were used. The electronic search was supplemented with a manual search of the reference lists of relevant articles.

STUDY SELECTION

All articles that gave mortality figures following endovascular surgery for RAAAs were included in the analysis. Only patients with true ruptures were included. Those who underwent emergent endovascular repair of an acute, symptomatic, nonruptured aneurysm had been excluded. Studies were also rejected if they described only selected groups of patients (such as octogenarians) or were single-case reports. In the case of studies reporting on the same clinical material, the most recent study or the larger of the two was selected for analysis.

DATA EXTRACTION

Selection of studies and data abstracting were performed by one of the authors (C.D.K.). The primary outcome measure was perioperative mortality, defined as all perioperative, in-hospital, and 30-day mortality. When information on both in-hospital and 30-day mortality was available, the latter was used for the analysis. Information on sex, age, type of anesthesia, endograft configuration, hemodynamic instability, use of intra-aortic occlusion balloon, conversion to open repair, and the development of abdominal compartment syndrome was also sought. If available, mortality rates of patients who underwent concurrent open repair were also recorded. Series reporting on both endovascular and concurrent open repair were combined to estimate overall mortality rates using both approaches.

STATISTICAL ANALYSIS

Separate meta-analyses were performed for operative mortality after (1) endovascular repair, (2) concurrent open repair, and (3) endovascular and open repair in series reporting both. Results were expressed as pooled proportions (percentage) with 95% confidence intervals (CIs). Heterogeneity across the studies was evaluated using the Cochran *Q* statistic, and random-effects models were used to incorporate any heterogeneity present.[54] Significance was set at $P < .05$. Statistical analysis was performed using StatsDirect (version 2.6.2; StatsDirect Ltd, Altrincham, England).

RESULTS

Literature search identified 46 relevant articles.[6-52] Of these, 7 articles were excluded because they were reviews or invited commentaries,[39,41,44,48-51] 7 because they were series from the same institutions with duplicate clinical material,[36-38,40,42,45,46] 1 because it was a study on octogenarians,[43] and 2 because they were single-case reports.[6,47] This left 29 studies for analysis, reporting on a total of 897 patients.[8-36] Basic data are presented in **Table 1**. Information on sex was available in 483 patients; 417 (86%) were men. The mean age was 74.2 years (range, 26-99 years).

MORTALITY AFTER ENDOVASCULAR REPAIR

In-hospital and/or 30-day mortality ranged between 0% and 54% in different series (**Figure 1**). The highest mortality was encountered in the context of the single randomized trial identified.[31] The overall mortality across the whole population was 29.2% (262 patients). There was significant heterogeneity between studies (Cochran $Q_{28}=64.83$; $P<.001$). The pooled proportion for mortality after endovascular repair was 24.5% (95% CI, 19.8%-29.4%).

MORTALITY AFTER CONTEMPORARY OPEN REPAIR

A total of 19 studies provided mortality data of both open and endovascular repair during the same period from the same surgical unit, with the most cases derived from a large US multicenter study (**Table 2**).[29] The mortality rates in the open repair groups ranged from 0% to 62.5%, and there was significant heterogeneity between studies (Cochran $Q_{18}=30.42$; $P=.03$). A total of 2895 of 6107 patients died after open repair. The pooled proportion of the mortality figures was 44.4% (95% CI, 40.0%-48.8%) (**Figure 2**).

TOTAL MORTALITY IN STUDIES REPORTING CONTEMPORARY ENDOVASCULAR AND OPEN REPAIR

When the data from the above 19 studies were pooled, the total mortality rates for RAAAs treated in surgical units that offered both endovascular and open repair ranged from 8% to 54%. Again, there was significant heterogeneity (Cochran $Q_{18}=89.73$; $P<.001$). The pooled proportion of the mortality figures was 35% (95% CI, 30%-41%) (**Figure 3**).

LOCAL VS GENERAL ANESTHESIA

Information on the type of anesthesia was available in 468 patients. A total of 137 patients (29%) were operated on while under local anesthesia; 220 received general anesthesia (47%); 110 of the procedures (24%) began with local anesthesia and were converted to general anesthesia; and 1 patient received epidural anesthesia.

BIFURCATED VS AORTOUNIILIAC/AORTOUNIFEMORAL APPROACH

Details on the type of stent graft were available in 544 patients. A bifurcated aortobiiliac stent graft was used in 261 cases (48%), and an aortouniiliac/aortounifemoral stent graft was used in 260 (48%). A straight tube graft was used in 17 patients.

Table 1. Studies Reporting Endovascular Management of RAAAs

Source (Country of Study)	ER	Operative Mortality	Local Anesthesia	Bifurcated Approach	Unstable Patients	Balloon Occlusion	Primary Conversion to OR	Abdominal Compartment Syndrome
	No.							
Greenberg et al,[8] 2000 (United States and Sweden)	3	0	0	0	2	2	0	0
Hinchliffe et al,[9] 2001 (United Kingdom)	20	9	0	0	4	2	3	NA
Veith and Ohki,[10] 2002 (United States)	25	3	0	0	8	8	0	2
Yilmaz et al,[11] 2002 (the Netherlands)	17	4	NA	NA	12	0	0	NA
Van Herzeele et al,[12] 2003 (Belgium)	9	2	0	3	6	NA	0	1
Scharrer-Palmer et al,[13] 2003 (Germany)	24	5	NA	19	4	0	1	0
Resch et al,[14] 2003 (Sweden)	21	4	12	9	5	5	NA	1
Lee et al,[15] 2004 (United States)	13	1	1	13	0	0	0	NA
May et al,[16] 2004 (Australia)	3	0	NA	3	NA	NA	NA	NA
Lombardi et al,[17] 2004 (United States)	5	0	1	4	0	0	0	0
Arya et al,[18] 2004 (United Kingdom)	14	3	NA	3	0	NA	1	0
Gerassimidis et al,[19] 2005 (Greece)	23	9	17	14	9	0	0	0
Larzon et al,[20] 2005 (Sweden)	15	2	2	15	11	11	1	1
Brandt et al,[21] 2005 (Germany)	11	0	0	3	NA	NA	0	NA
Peppelenbosch et al,[22] 2005 (the Netherlands and Belgium)	35	8	0	3	20	NA	NA	NA
Alsac et al,[23] 2005 (France)	17	4	1	8	1	1	3	1
Hechelhammer et al,[24] 2005 (Switzerland)	37	4	28	35	3	3	1	3
Vaddineni et al,[25] 2005 (United States)	9	2	0	9	0	0	0	NA
Castelli et al,[26] 2005 (Italy)	25	5	0	21	7	3	0	1
Dalainas et al,[27] 2006 (Italy)	20	8	20	11	NA	20	0	1
Oranen et al,[28] 2006 (the Netherlands)	34	6	27	NA	NA	NA	1	1
Greco et al,[29] 2006 (United States)	290	114	NA	NA	36	NA	20	NA
Visser et al,[30] 2006 (the Netherlands and United States)	26	8	0	24	2	NA	2	1
Hinchliffe et al,[31] 2006 (United Kingdom)	13	7	0	0	5	0	2	NA
Acosta et al,[32] 2006 (Sweden)	56	19	NA	23	47	NA	NA	3
Peppelenbosch et al,[33] 2006 (international multicenter[a])	49	17	16	0	21	3	3	NA
Coppi et al,[34] 2006 (Italy)	33	10	12	7	15	4	3	1
Franks et al,[35] 2006 (United Kingdom)	10	1	NA	NA	3	NA	1	0
Mehta et al,[36] 2006 (United States)	40	7	0	34	10	7	2	7

Abbreviations: ER, endovascular repair; NA, not available; OR, open repair: RAAAs, ruptured abdominal aortic aneurysms.
[a] International multicenter study from Eidhoven and Enschede, the Netherlands; Belfast, Northern Ireland; Perugia, Italy; Montreal, Quebec, Canada; Heerlen, the Netherlands; Helsinki, Finland; Brugge and Ghent, Belgium; London, Ontario, Canada; and Utrecht, the Netherlands.

HEMODYNAMIC INSTABILITY

We used the term *hemodynamic instability* loosely, accepting authors' arbitrary definitions, though they were different in different studies (**Table 3**). In fact, 12 of the 29 studies did not provide a definition at all. As a criterion for hemodynamic instability, most studies used a drop in systolic blood pressure, 5 studies used a combination of falling blood pressure and level of consciousness, 2 used a combination of blood pressure and the presence of cardiac arrest or severe arrhythmia, and 1 study used loss of consciousness as the only criterion. Studies also differed with regard to the cut-off value in the systolic blood pressure below which a patient was considered unstable. According to the study authors' criteria, hemodynamic instability was present in 231 of 829 patients (28%) at the time of intervention.

USE OF INTRA-AORTIC OCCLUSION BALLOON

Twenty articles provided information on the use of aortic occlusion balloons. In 14 of these, investigators used balloon occlusion selectively, whereas 6 centers never used one. The rate of use in each study ranged from 0% to 100%. Across the total population, 69 of 409 patients (17%) required balloon occlusion.

CONVERSION TO OPEN REPAIR

Primary, ie, intraoperative, conversion to open repair was necessary in 44 of 784 patients (6%). Details regarding the reasons for conversion were available in 24 patients (**Table 4**). Data on outcome were available in 18 patients, of whom only 4 survived, for an overall mortality of 78%. Additionally, there were 10 secondary conversions, of which 6 occurred during hospital stay and 4 were late conversions.

ABDOMINAL COMPARTMENT SYNDROME

Only 1 study provided an accurate definition of abdominal compartment syndrome.[32] Ten studies gave no details at all, whereas in the remaining 19 series, the rate of abdominal compartment syndrome was 5.5% (24 of 439).* Treatment details were available in 17 cases. Twelve patients underwent open evacuation of the retroperitoneal hematoma, 1 had percutaneous drainage,[20] and 4 had been treated conserva-

**References 8, 10, 12-14, 17-20, 23, 24, 26-28, 30, 32, 34-36.*

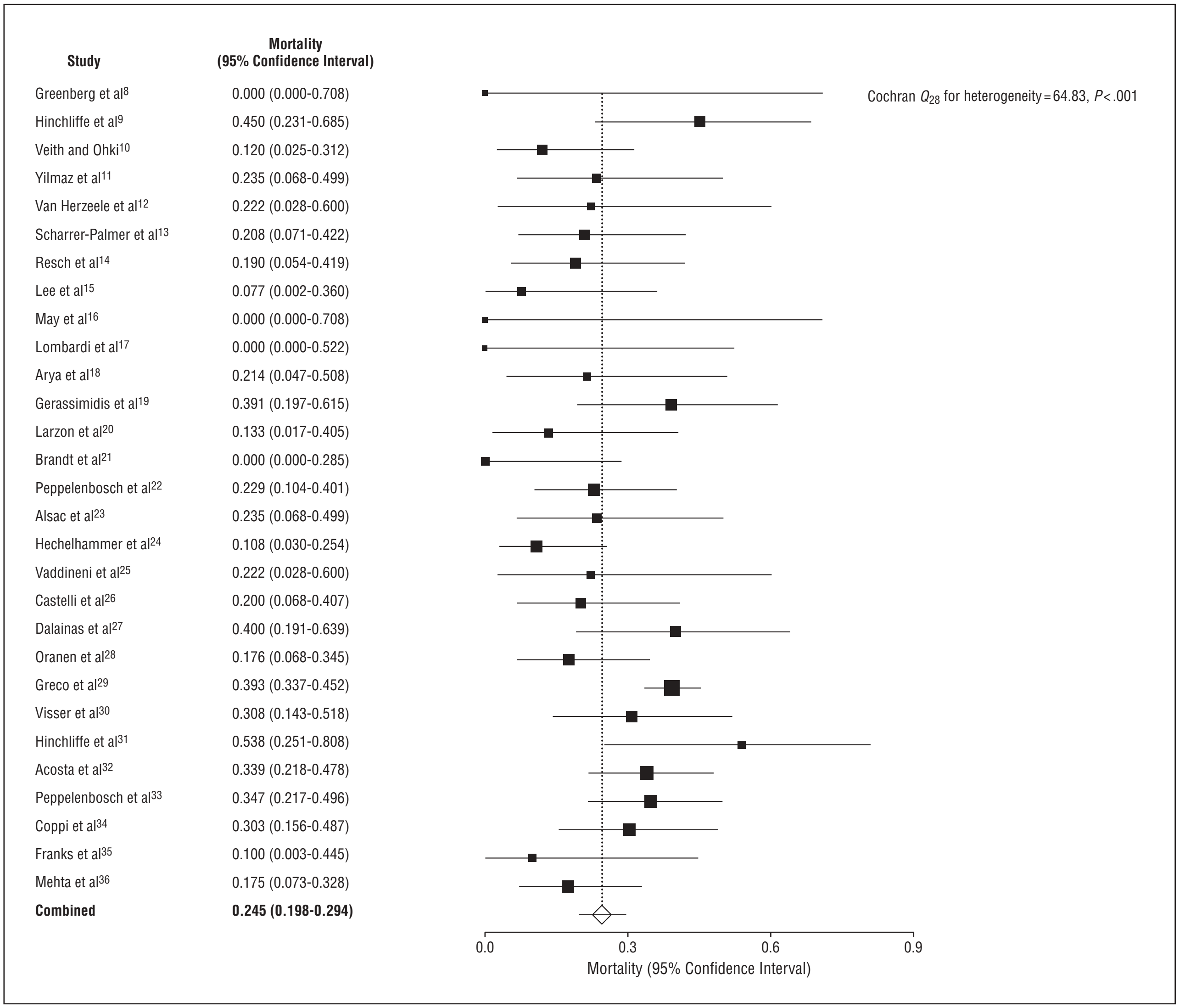

Figure 1. Forest plot (random-effects proportion meta-analysis) of mortality after endovascular repair in 29 studies.

tively with supportive measures, such as intubation, ventilation, relaxation, and temporary hemofiltration.[38]

COMMENT

Endovascular repair for an RAAA was first described in 1994 by Yusuf et al.[6] Although this was the first published case, the first actual case was performed in April of 1994 at Montefiore Medical Center/Albert Einstein College of Medicine in New York, New York.[7,10] Since then, endovascular RAAA repair has evolved and become the preferred treatment option in many specialist centers.[10,14,19,30,32,43,47] Endovascular repair is appealing because patients often present in extremis and are elderly individuals with multiple comorbidities. An endovascular approach may avoid compounding the physiological stress of rupture with the surgical stresses of midline laparotomy, aortic cross-clamping, and the iatrogenic injuries that often occur during open repair. The third-space losses, hypothermia, blood loss, and coagulopathy are also minimized.[10,43,47] This systematic review represents the largest collective experience of endovascular repair for RAAAs in the literature and documents the pooled mortality figures from 29 published series. We have sought to include only true ruptures, excluding acute symptomatic AAAs, which have a much better prognosis, as many previous reports in the literature, including these cases, are inevitably biased and reduce the overall mortality rate reported.

The pooled mortality after endovascular repair for RAAA was 24.5%. A total of 19 studies provided mortality data for contemporary open repair during the same period with a mortality of 44.4%. Interestingly, when pooling data from the above 19 studies from surgical units that offered their patients both open and endovascular repair, the overall RAAA mortality of 35% is much lower than that which is generally accepted,[5,55] which may suggest that integrating both treatment options may benefit patients overall. This theory is supported by a Canadian study that, using predictive models, demonstrated improved RAAA mortality following the introduction of an endovascular program.[56] We have also reported several

Table 2. Studies on Endovascular Repair of RAAAs Reporting Mortality of Contemporary Open Repair

Source	30-Day Mortality, No. (%)
Veith and Ohki[10]	0
Yilmaz et al[11]	12 (41)
Resch et al[14]	8 (35)
Lee et al[15]	1 (25)
May et al[16]	49 (56)
Larzon et al[20]	12 (46)
Brandt et al[21]	2 (15)
Alsac et al[23]	10 (50)
Vaddineni et al[25]	4 (26)
Castelli et al[26]	10 (47.6)
Dalainas et al[27]	5 (62.5)
Greco et al[29]	2627 (47.7)
Visser et al[30]	9 (31)
Hinchliffe et al[31]	6 (43)
Acosta et al[32]	48 (45)
Peppelenbosch et al[33]	20 (39)
Coppi et al[34]	42 (46)
Franks et al[35]	7 (54)
Mehta et al[36]	23 (51)

key factors that may have a major effect on outcome, namely, type of anesthesia, endograft choice, hemodynamic instability, use of occlusion balloon, conversion to open repair, and the development of abdominal compartment syndrome.

The reported mortality rates after endovascular repair vary a great deal in the literature. Useful data can be extracted from 2 registries[56,57] and 4 meta-analyses.[58-61] Veith,[57] in a collective world experience with information from 48 centers on 442 RAAAs, reported a 30-day mortality of 18%. In the United Kingdom National Vascular Database, which includes 51 RAAAs, the 30-day mortality was 29%.[58] Harkin et al,[59] reporting on the Belfast meta-analysis of 34 studies, quoted a mortality of 18%. A Dutch meta-analysis examined 10 studies with 148 endovascular procedures and estimated the pooled mortality to be 22%.[60] In a Canadian meta-analysis, the pooled mortality in 18 studies (436 patients) was 21%.[61] Finally, a Cambridge meta-analysis of 23 studies and 730 endovascular procedures for acute AAAs, both ruptured and symptomatic cases, calculated a pooled mortality of 30%.[62] All of these results are much better than those traditionally reported in the literature for open repair. However, these values may reflect increasing experience and patient selection. Furthermore, they originate from pioneering centers from around the world with significant experience in elective endovascular aneurysm repair.[50]

It should be stressed that comparison of endovascular with open RAAA repair may be misleading, because endovascular repair cannot be performed on all patients and selection bias may explain the superior performance of any given strategy. Many studies exclude patients with unfavorable anatomy and those deemed unstable from endovascular repair. In the Belfast meta-analysis,[59] the pooled mortality was 18% and 34% after endovascular and open repair, respectively. The Dutch meta-analysis attempted to compare open and endovascular repair after adjustment for the presence of hemodynamic instability.[60] The pooled mortality was 22% for endovascular and 38% for open repair. The crude odds ratio of mortality for endovascular compared with open repair was 0.45 (95% CI, 0.28-0.72), 0.67 (95% CI, 0.31-1.44) after adjustment for patients' hemodynamic condition; a nonsignificant benefit was observed for endovascular repair. Finally, in the Cambridge meta-analysis, emergency endovascular repair for acute symptomatic aneurysms was associated with a significant reduction in mortality (pooled odds ratio, 0.624; 95% CI, 0.518-0.752; $P < .001$).[62]

The feasibility of performing endovascular repair under local anesthetic and intravenous sedation has been demonstrated in elective cases.[51,52] Nevertheless, most emergency endovascular procedures are still performed under general anesthesia. To date, only a few centers plan to use local anesthesia as the anesthetic technique of choice,[19,24] whereas others use it selectively. Less than one-third of patients in this systematic review had been operated on under local anesthesia. Another 24% of the procedures were begun with local and were converted to general anesthesia. Usual reasons for conversion were loss of consciousness and severe pain.[9,19,50] Movement artifact due to patient discomfort has been reported to be the reason for inadvertent coverage of the renal arteries or lower placement of the main body of the device, resulting in inadequate aneurysm exclusion.[9,19,50] Despite this, the use of local anesthesia may be the most crucial factor in avoiding major hemodynamic disturbance and may account for the better chances of survival in patients undergoing emergent endovascular repair.

The choice of endograft configuration in the RAAA setting remains a matter for debate and user preference. The decision depends on several factors, including aneurysm anatomy, expertise, preference of the operator, and endograft availability. If one opts for the anatomical bifurcated approach, a major concern is the time spent to cannulate the contralateral stump of the main device and deploy the contralateral iliac limb, because of the ongoing hemorrhage. If an aortouniiliac/aortounifemoral approach is chosen, the technical simplicity, speed of deployment, and higher eligibility rate should be weighed against all of the disadvantages of an extraanatomic option. Nevertheless, both choices have their proponents and opponents, as reflected by the roughly equal numbers of bifurcated and aortouniiliac/aortounifemoral endografts used in this collective world experience.

Hypotensive hemostasis is also an important advance in the management of RAAAs. This approach has been proved beneficial in other circumstances, such as major gastrointestinal bleeding and trauma, including open repair of RAAAs.[63,64] The principle of limited intravenous resuscitation until complete endovascular aneurysm exclusion was first advocated by Veith et al[10,43,47] and subsequently adopted by many others. Indeed, the group from University Hospital Zurich has advocated active lowering of blood pressure with vasodilator drugs in the treatment of ruptured aneurysms.[24,38] Some surgeons also advocate the selective use of intra-aortic occlusion balloons in hemodynamically unstable patients in whom adequate systolic blood pressure cannot be

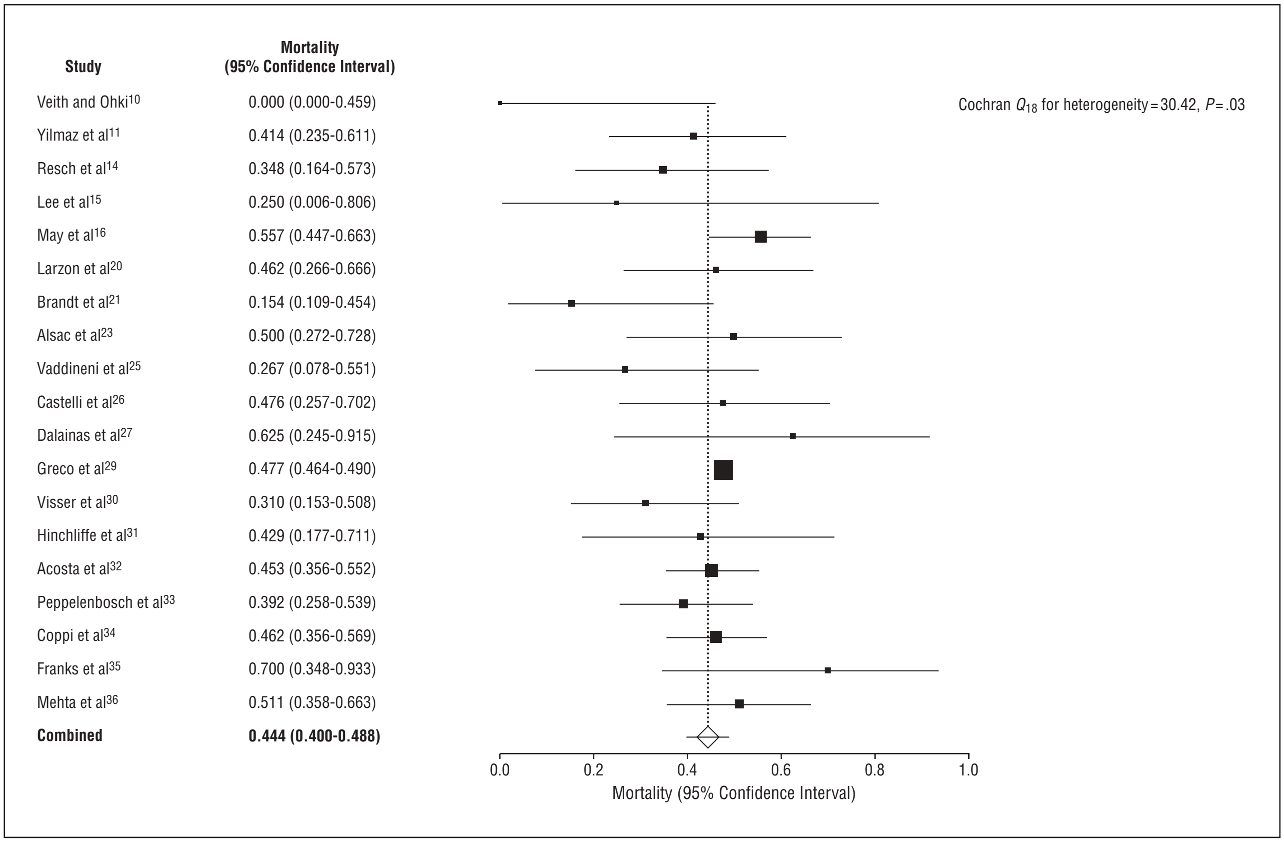

Figure 2. Forest plot (random-effects proportion meta-analysis) of mortality in the contemporary open repair groups.

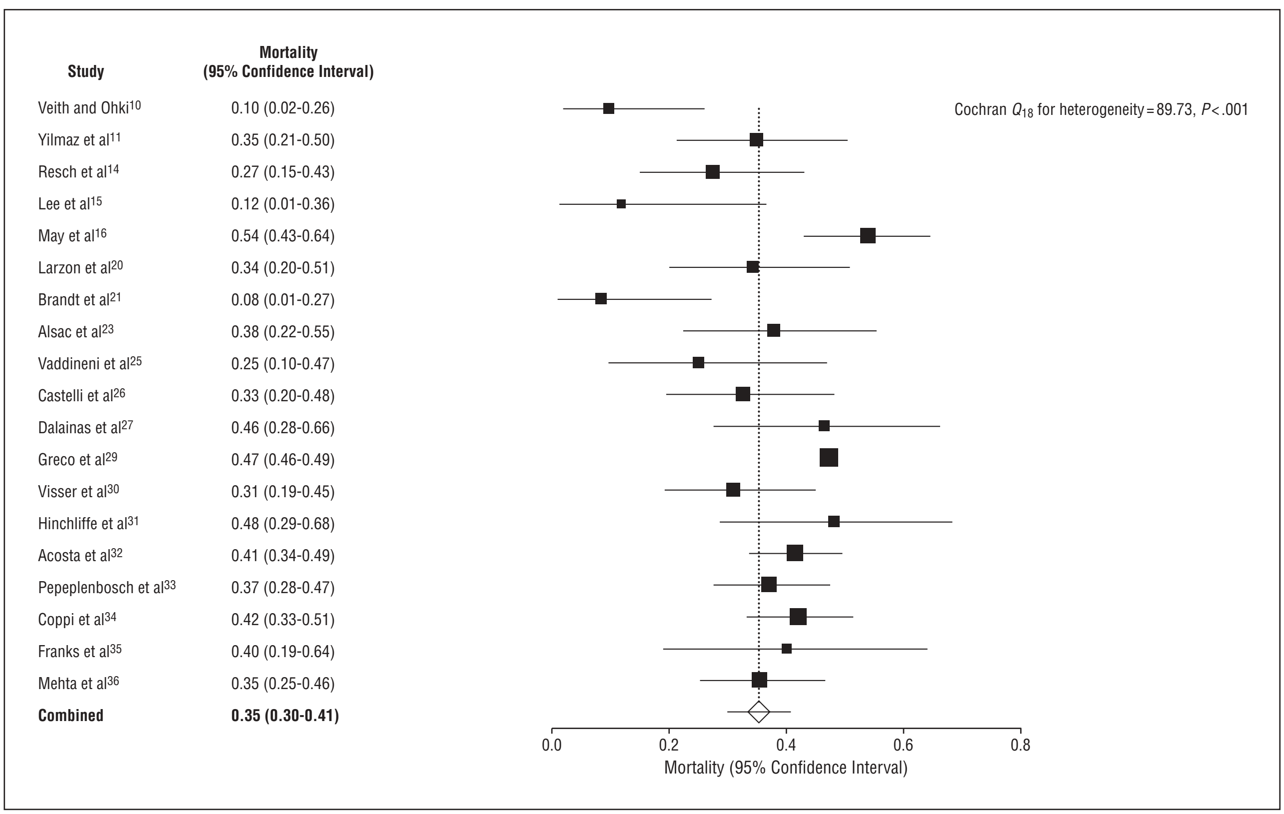

Figure 3. Forest plot (random-effects proportion meta-analysis) of total mortality in 19 studies reporting outcome for both endovascular and concurrent open repair groups.

Table 3. Definition of Hemodynamic Instability Across 29 Studies

Source	Defining Criteria for Hemodynamic Instability
Greenberg et al[8]	NA
Hinchliffe et al[9]	SBP <90 mm Hg
Veith and Ohki[10]	SBP <50-70 mm Hg (all patients were taken directly to the operating room for angiography)
Yilmaz et al[11]	SBP <100 mm Hg
Van Herzeele et al[12]	SBP <70 mm Hg
Scharrer-Palmer et al[13]	NA
Resch et al[14]	NA
Lee et al[15]	SBP <80 mm Hg or reduced mentation
May et al[16]	NA
Lombardi et al[17]	NA
Arya et al[18]	NA
Gerassimidis et al[19]	SBP <80 mm Hg and/or reduced mentation
Larzon et al[20]	SBP <80 mm Hg at any time from arrival until induction to anesthesia
Brandt et al[21]	NA but excluded all "unstable" patients
Peppelenbosch et al[22]	SBP <90 mm Hg
Alsac et al[23]	Excluded patients with profound hypovolemic shock (SBP <80 mm Hg and/or cardiac arrest) but included those with moderate instability, ie, SBP >80 mm Hg and no severe cardiac arrhythmia
Hechelhammer et al[24]	NA
Vaddineni et al[25]	SBP <80 mm Hg and/or reduced mentation
Castelli et al[26]	NA ("profound hemorrhagic shock")
Dalainas et al[27]	NA ("profound hemorrhagic shock")
Oranen et al[28]	NA
Greco et al[29]	NA
Visser et al[30]	SBP <90 mm Hg. Those who were "hemodynamically too unstable" (ie, SBP <70 mm Hg with no adequate verbal reply) were excluded and underwent open repair
Hinchliffe et al[31]	SBP <100 mm Hg
Acosta et al[32]	Circulatory instability: loss of consciousness, either transient or permanent, prior to operation
Peppelenbosch et al[33]	Patients with moderate instability (SBP 60-100 mm Hg, without cardiac arrhythmia) underwent preoperative CT to determine suitability for endovascular repair; patients with severe instability (SBP <60 mm Hg, with cardiac arrhythmia) were transferred directly to the operating room for angiography
Coppi et al[34]	Loss of consciousness with or without a SBP <80 mm Hg after fluid resuscitation
Franks et al[35]	SBP <100 mm Hg
Mehta et al[36]	SBP <80 mm Hg

Abbreviations: CT, computed tomography; NA, not available; SBP, systolic blood pressure.

Table 4. Immediate Conversion to Open Repair in the 24 Patients With Available Information

Reasons for Immediate Conversion	No. of Cases
Access difficulties	5
Type I endoleak and/or stent-graft migration	4
Continued blood loss	4
Inadvertent renal artery overstenting	1
Stent-graft thrombosis	1
Inability to catheterize the contralateral limb	1
Unspecified endoleak	1
Technical error	1
Information not available	6

maintained despite resuscitation measures. Others consider this an additional step in the procedure that may consume precious time and favor expeditious graft deployment without the use of occlusion balloons.[50] However, there is no doubt that an occlusion balloon may provide extra time in a very unstable patient, in cases of intraoperative difficulties, or when an immediate conversion to open repair becomes necessary.[10]

Hemodynamic instability is, perhaps, the single most important determinant of survival in patients with RAAA undergoing endovascular repair. Although the first and many other early cases treated by the surgeons at Montefiore Medical Center/Albert Einstein College of Medicine were unstable and, in fact, required balloon control,[10,43,47] in other centers, particularly during the initial experience, hemodynamic instability was considered a contraindication and the procedure was only offered to stable, anatomically suitable patients who could tolerate the inevitable logistic delays. This meant exclusion of all unstable patients who would then be considered for open repair or terminal conservative care. What constitutes hemodynamic instability differs widely between studies because of differing criteria of blood pressure and level of consciousness. This implies a great heterogeneity between studies with regard to case selection, which would certainly have an impact on reported mortality rates. Nevertheless, hemodynamic instability does not preclude endovascular repair. In fact, with growing experience, several centers are now offering endovascular repair to hemodynamically unstable patients.[19,34,36,56] Hemodynamic instability was present in just more than one-fourth of patients included in this review. Unstable patients may particularly benefit from endovascular techniques and should not be excluded.[10,43,47] These patients do badly with open repair anyway and they may have the most to gain from endovascular repair.[10,34,36,43,47,56]

A potential complication of endovascular repair for RAAA is the development of abdominal compartment syndrome. In contrast to open surgery, endovascular repair does not allow evacuation of the retroperitoneal hematoma, which may theoretically lead to an increased incidence of compartment syndrome. This entity was first recognized by Veith et al,[7,10,43,47] but its systematic treatment has been promoted by the surgeons at University Hospital Zurich.[24,38] The syndrome's incidence across this meta-analysis was calculated as 5.5%, but whether it is more common than after open repair remains to be seen. It is important to recognize this complication and aggressively treat it.

In conclusion, this systematic review demonstrates that endovascular repair is feasible in selected patients and may be associated with a mortality rate equivalent to or better than those of contemporary series and historical reports of conventional open repair. Many specialist units have now adopted endovascular repair as a first-line option for patients considered anatomically suitable and continue to expand their inclusion criteria for those previously deemed unsuitable due to hemodynamic instability. However, owing to the lack of evidence from good-quality randomized controlled trials, the benefit of endovascular repair over open surgery has not been definitively proven. Furthermore, the highly selected nature of patients in most series would tend to exclude those at highest risk and, as such, improvements in mortality should be treated with caution. Despite this, there is emerging evidence that specialist centers that offer both treatment options may attain an improvement in overall RAAA mortality. Additional evidence from large prospective studies and registries would certainly be required, not to clarify which technique is superior, but to define more clearly the role of endovascular repair as an additional therapeutic option for RAAAs.

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INVITED CRITIQUE

I only run for fire and hemorrhage.

Gershon Efron, MD, circa 1996

A ruptured abdominal aortic aneurysm demands immediate diagnosis and a skilled team to deliver operative care in an expedient and effective manner. General refinement in aortic surgery to address aneurysmal disease has greatly improved contemporary results for elective repair, yet similar reductions in the morbidity and mortality rate after open repair of RAAAs have stalled in the range of 40% to 50% for decades. The advent of endovascular aneurysm repair (EVAR) created a new treatment paradigm for eventual expansion into the arena of RAAA. It is no surprise that surgeons who were frustrated by experiences with RAAAs have recognized the many benefits of EVAR to address this life-threatening condition. Karkos and colleagues have provided us with a sound meta-analysis of 29 publications reviewing 897 patients with RAAAs, thus offering us a window to see the true state