Invited Commentary

Bundles of Care for Patients With Ruptured Abdominal Aortic Aneurysms
Is Endovascular Repair the Solution?

Peyman Benharash, MD; William Toppen, MD

Is less really more? The answer appears complicated in the case of ruptured abdominal aortic aneurysms (rAAAs). Over the last 40 years, the mortality rate among patients who underwent surgical repair for this ominous disease has remained at 40% to 50%,[1] a staggering figure given advances in diagnosis, surgical technique, and perioperative care. Moreover, patients who survive the operation often die of multiorgan failure and late death in the intensive care unit. Given the success of endovascular aneurysm repair (EVAR) for nonruptured aneurysms,[2] it seems logical that a less invasive approach to ruptures would improve survival and reduce the number of complications that are often associated with major open repairs. Surprisingly, however, a number of randomized European trials, most notably the IMPROVE (Immediate Management of Patients With Rupture: Open versus Endovascular Repair) trial,[3] have demonstrated that the nonselective use of EVAR for rAAAs does not yield a survival advantage.

Related article

How can we explain such a discrepancy between the expected and observed outcomes of patients who undergo EVAR for a ruptured aneurysm? In this issue of *JAMA Surgery*, Ullery and colleagues[4] share their experience of EVAR vs open repair for rAAAs in the setting of a care bundle rather than with regard to surgical technique per se. They evaluated 88 patients over a 17-year period and implemented an endovascular-first treatment strategy in the latter 7 years. This algorithm included rapid transfer, triage, and imaging; local or no anesthesia; use of an aortic occlusion balloon; permissive hypotension; and use of decompressive laparotomy in select cases. During the protocol period, two-thirds of patients underwent EVAR, and the overall mortality rate decreased by nearly half to 14%. Although Ullery and colleagues[4] should be applauded for their institutional expertise in treating rAAAs, they make an interesting observation: there was no difference in mortality between open repair and EVAR. This finding may finally explain why implementation of EVAR alone does not affect outcomes.

As proven in many other facets of quality improvement, the impact of bundles extends beyond the individual techniques themselves.[5] In fact, Ullery and coworkers[4] used the principles of trauma resuscitation to shape their final protocol: rapid control of hemorrhage, permissive hypotension, minimal early anesthetic, and modern resuscitation strategies postoperatively (such as early extubation and selective use of decompressive laparotomy). They should be congratulated for their remarkable outcomes and for sparking renewed interest in the use of EVAR for rAAAs.

ARTICLE INFORMATION

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Original Investigation | PACIFIC COAST SURGICAL ASSOCIATION

Association of an Endovascular-First Protocol for Ruptured Abdominal Aortic Aneurysms With Survival and Discharge Disposition

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IMPORTANCE Mortality after an open surgical repair of a ruptured abdominal aortic aneurysm (rAAA) remains high. The role and clinical benefit of ruptured endovascular aneurysm repair (rEVAR) have yet to be fully elucidated.

OBJECTIVE To evaluate the effect of an endovascular-first protocol for patients with an rAAA on perioperative mortality and associated early clinical outcomes.

DESIGN, SETTING, AND PARTICIPANTS Retrospective review of a consecutive series of patients presenting with an rAAA before (1997-2006) and after (2007-2014) implementation of an endovascular-first treatment strategy (ie, protocol) at an academic medical center.

MAIN OUTCOMES AND MEASURES Early mortality, perioperative morbidity, discharge disposition, and overall survival.

RESULTS A total of 88 patients with an rAAA were included in the analysis, including 46 patients in the preprotocol group (87.0% underwent an open repair and 13.0% underwent an rEVAR) and 42 patients in the intention-to-treat postprotocol group (33.3% underwent an open repair and 66.7% underwent an rEVAR; P = .001). Baseline demographics were similar between groups. Postprotocol patients died significantly less often at 30 days (14.3% vs 32.6%; P = .03), had a decreased incidence of major complications (45.0% vs 71.8%; P = .02), and had a greater likelihood of discharge to home (69.2% vs 42.1%; P = .04) after rAAA repair compared with preprotocol patients. Kaplan-Meier analysis demonstrated significantly greater long-term survival in the postprotocol period (log-rank P = .002). One-, 3-, and 5-year survival rates were 50.0%, 45.7%, and 39.1% for open repair, respectively, and 61.9%, 42.9%, and 23.8% for rEVAR, respectively.

CONCLUSIONS AND RELEVANCE Implementation of a contemporary endovascular-first protocol for the treatment of an rAAA is associated with decreased perioperative morbidity and mortality, a higher likelihood of discharge to home, and improved long-term survival. Patients with an rAAA and appropriate anatomy should be offered endovascular repair as first-line treatment at experienced vascular centers.

Invited Commentary

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Despite the first successful endovascular repair of a ruptured abdominal aortic aneurysm (rAAA) reported in 1995,[1] widespread adoption of ruptured endovascular aneurysm repair (rEVAR) has been more cautious than that of elective endovascular repair owing to a paucity of level I data during the last 2 decades documenting a similar clinical benefit in an emergency setting. Nevertheless, acceptance of rEVAR has gained considerable momentum in recent years owing to an increasing body of literature showing rEVAR to be associated with improved perioperative and early survival among patients presenting with an rAAA.[2-7] These reports, however, are limited mostly to retrospective and observational data, with the few studies examining midterm outcomes noting mixed results.[8,9]

Consistent with national trends, use of rEVAR has steadily increased at our institution in recent years, and this less-invasive treatment strategy was formally integrated into a structured algorithmic approach to the management of patients with an rAAA at our institution in 2007. The objective of the present study was to investigate whether the implementation of our endovascular-first emergency protocol for the treatment of an rAAA would translate into improved clinical outcomes and discharge disposition compared with conventional open repair.

Methods

The medical records of all consecutive patients presenting to a single academic medical center who received a diagnosis of rAAA between July 1997 and July 2014 were included for analysis. Data were deidentified. Approval for this study was obtained by the Stanford University institutional review board. Clinical and procedural data, as well as available images, were reviewed. Prior to 2007, patients presenting with an rAAA primarily underwent an open repair. In January 2007, we implemented our endovascular-first algorithm for the management of patients with an rAAA, which included an initial eligibility assessment for an intention-to-treat EVAR protocol. The present study serves as a retrospective nonrandomized intention-to-treat cohort study of patients with an rAAA who were treated following implementation of this protocol compared with preprotocol patients.

Endovascular-First Approach

Our current treatment protocol for patients with an rAAA is similar to those previously published[2,4,10,11] and is highlighted in **Figure 1**. A rapid clinical assessment stratified patients into 1 of 2 groups based on physiologic parameters. Patients without prior radiographic images underwent immediate computed tomographic angiography of the abdomen and pelvis; 3-dimensional reconstructive images were not routinely obtained. Anatomic suitability for EVAR was assessed by the operating surgeon based on his or her experience and on the instructions for use of devices used routinely at our institution during the study period. In general, exclusion criteria for EVAR included a neck aneurysm with a diameter of greater than 32 mm, a neck length of less than 10 mm, and a neck angulation of greater than 60°; severe iliac tortuosity; or an external iliac diameter of less than 6 mm. As our experience with rEVAR increased over the study period, we rapidly accepted cases with a less-favorable neck anatomy and became less strict with these criteria to prevent life-threatening hemorrhages.

All cases were performed in a standard operating room with a mobile C-arm fluoroscopy machine. Patients were prepared for surgery while they were still awake and were managed initially with local or no anesthesia. A transfemoral intra-aortic occlusion balloon (CODA balloon; Cook Medical) with 12Fr sheath support was inserted into the suprarenal aorta in hemodynamically unstable patients. If patients exhibited significant hypotension, the occlusion balloon was inflated to profile in order to optimize hemodynamics. Heparin was used selectively in all cases. Open rAAA repairs were typically performed using a transperitoneal approach so as to facilitate initial angiography and placement of the intra-aortic occlusion balloon from the supine position.

Decompressive laparotomy was performed immediately following rEVAR if there was concern for abdominal compartment syndrome based on a constellation of elevated peak airway pressures, increased bladder pressures, massive volume resuscitation, abdominal distention, or persistent hemodynamic derangements. All patients were transferred to the intensive care unit (ICU) postoperatively regardless of repair type. When renal function permitted, patients underwent computed tomographic angiography prior to hospital discharge. Postoperative follow-up included a clinical examination and cross-sectional imaging at 1, 6, and 12 months, and annually thereafter for patients who underwent an rEVAR, whereas those undergoing open repair were seen at 1 month with cross-sectional imaging and annually thereafter with abdominal ultrasonography.

Statistical Analyses

Primary outcome measures were 30-day mortality, discharge disposition, and overall survival at latest follow-up. Late mortality was determined from the medical records, primary care physicians, and the Social Security Death Index. Incidence of postoperative complications was recorded as a secondary outcome. All clinical outcome measures were tabulated and compared between patients undergoing treatment before and after implementation of our contemporary endovascular-first approach to rAAA repair.

Descriptive statistics were used to assess demographics, baseline comorbidities, and aneurysm characteristics. Univariate analyses were calculated using the Wilcoxon rank sum test and the Pearson χ^2 test for continuous and categorical variables, respectively. Identified univariate associations with $P < .10$ were subsequently analyzed within a multivariate model to identify independent predictors of primary outcomes. Survival rates were estimated using Kaplan-Meier methods, with log-rank tests used to assess differences in event-free survival. Univariate and multivariate Cox proportional hazards models were used to identify dependent and independent factors affecting survival, respectively. A $P < .05$ was considered statistically significant for all analyses. All calculations were performed in Stata version 12.0 (StataCorp LP).

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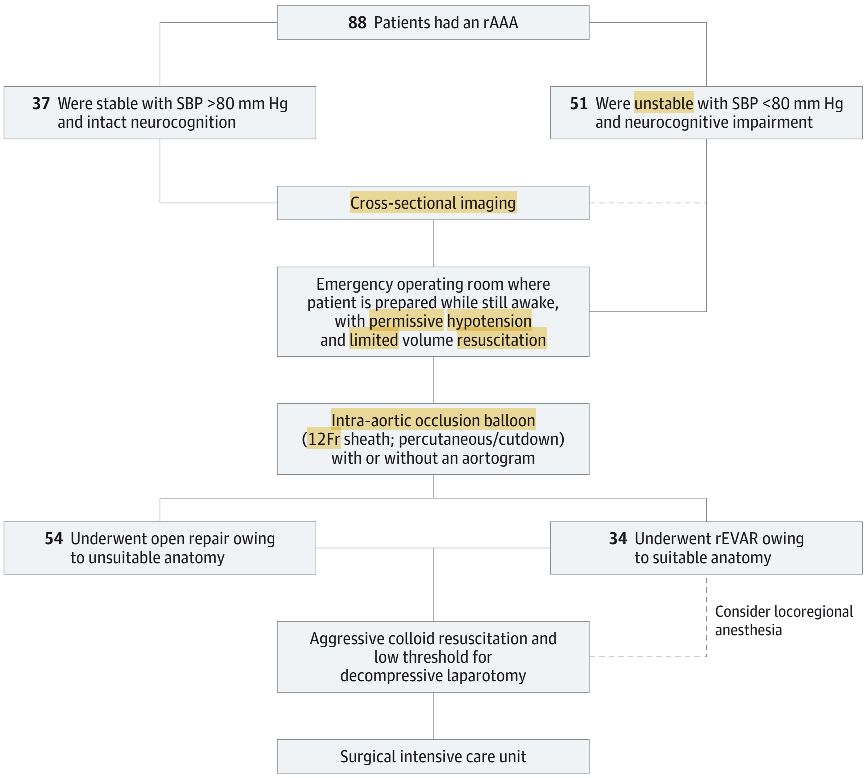
Figure 1. Contemporary Endovascular-First Approach for the Treatment of 88 Patients With a Ruptured Abdominal Aortic Aneurysm (rAAA)



rEVAR indicates ruptured endovascular aneurysm repair; SBP, systolic blood pressure.

Results

A total of 88 patients with an rAAA were treated at our institution during the study period, including 46 in the pre- and 42 in the post-EVAR intention-to-treat protocol groups. Both groups were similar based on baseline patient demographics and comorbid status (**Table 1**). An rEVAR was performed with significantly greater frequency during the postprotocol period than during the preprotocol period (66.7% vs 13.0%; *P* < .001). Juxtarenal/pararenal AAAs were noted in 30.4% of patients in the preprotocol period and in 16.7% of patients in the postprotocol period, which was not statistically different (*P* = .14). Surgeon volume was not associated with clinical outcome.

Two procedures involved implantation of an aorto-uni-iliac device with placement of femorofemoral crossover bypass graft. Two additional procedures involved placement of snorkel/chimney stent grafts in the celiac and superior mesenteric arteries to achieve a more proximal seal zone, including 1 case that required intentional coverage of the bilateral renal arteries.[12] No physician-modified devices were used during the study period. Intra-aortic occlusion balloon inflation was required for 18 patients (42.9%) during the postprotocol period. One patient (2.4%) required conversion to open repair owing to significant angulation of the infrarenal neck. During the postprotocol period, 14 patients underwent open repair instead of EVAR as a result of a juxtarenal/pararenal AAA (n = 7), concern for mycotic aneurysm or aortitis (n = 3), hemodynamic instability preventing assessment of rEVAR eligibility (n = 2), severe infrarenal neck angulation (n = 1), or aneurysmal involvement of the bilateral common iliac arteries (n = 1).

Early Mortality

Perioperative morbidity and mortality are noted in **Table 2**. In total, 9 patients died intraoperatively (5.9% who underwent an EVAR vs 13.0% who underwent an open repair; *P* = .47). The percentage of intraoperative deaths was not significantly different between the preprotocol and postprotocol groups (15.2% vs 4.8%; *P* = .16). Twelve patients (13.6%) survived open or endovascular rAAA repair but died within 30 days owing to multisystem organ failure (n = 5), cardiac arrest (n = 3), respiratory failure (n = 1), myocardial infarction (n = 1), or sepsis (n = 1). Multivariate analysis demonstrated 30-day mortality to be significantly lower for those patients undergoing rAAA repair during the postprotocol period (odds ratio, 0.16 [95% CI, 0.03-0.95]; *P* = .04), whereas history of prior stroke (odds ratio, 25.3 [95% CI, 1.95-327.00]; *P* = .01) was noted to be an independent risk factor for 30-day mortality (eTable 1 in the Supplement). Thirty-day mortality during the preprotocol and postprotocol periods was 32.6% and 14.3% (*P* = .03), respectively. There was no significant difference in 30-day mortality based on treatment type (27.4% for open repair vs 23.5% for EVAR; *P* > .99), sex (22.2% for female sex vs 32.1% for male sex; *P* > .99), age (19.7% for <80 years vs 36.4% for ≥80 years; *P* = .15), or need for inflation of intra-aortic occlusion balloon (21.1% for inflation vs 12.5% for no inflation; *P* = .68). Patients

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Table 1. Baseline Patient Characteristics and Perioperative Data

Characteristic	Patients, %						P Value[a]
	Preprotocol			Postprotocol			
	All (n = 46)	Open Repair (n = 40)	EVAR (n = 6)	All (n = 42)	Open Repair (n = 14)	EVAR (n = 28)	
Demographics							
Age, y							
<70	41.3	45.0	16.7	38.1	35.7	39.3	.58
70-79	30.4	32.5	16.7	40.5	50.0	35.7	
≥80	28.3	22.5	67.7	21.4	14.3	25.0	
Male sex	84.8	82.5	100	73.8	71.4	75.0	.20
Comorbidities							
CAD	45.7	42.5	66.7	40.5	28.6	46.4	.53
Hypertension	60.5	56.8	83.3	73.8	92.9	64.3	.90
CRI	15.2	15.0	16.7	19.0	28.6	14.3	.36
COPD	29.4	28.6	33.3	19.5	7.1	25.9	.32
Tobacco use	67.4	62.5	100	80.5	78.6	81.5	.20
Prior stroke	6.5	7.5	0.0	7.1	0.0	10.7	.81
Prior MI	14.7	12.5	0.0	4.9	0.0	7.4	.15
Hyperlipidemia	29.4	17.5	50.0	43.9	50.0	40.7	.20
Diabetes mellitus	17.6	10.0	33.3	12.2	7.1	14.8	.51
Preoperative data							
Hospital transfer	54.3	55.0	50.0	81.0	85.7	78.6	.004[b]
Diameter of AAA, mean (SD), cm	7.8 (2.0)	7.9 (2.0)	6.8 (1.4)	7.7 (2.2)	10.3 (3.0)	7.0 (1.2)	.61
SBP <80 mm Hg	60.9	60.0	66.7	54.8	64.3	50.0	.56
CPR before repair	10.9	12.5	0.0	2.4	7.1	0.0	.12
Hematocrit <25%	19.5	20.0	16.7	14.3	21.4	10.7	.81
Creatinine level ≥2 mg/dL	25.6	27.3	0.0	14.6	21.4	7.4	.28
Procedural data							
Free rupture	45.7	45.0	50.0	23.8	35.7	17.9	.03[b]
Intraoperative transfusions							
RBC, mean, units[c]	7.5	8.2	2.8	6.7	11.6	4.3	.14
FFP, mean (6 packs), units	3.3	3.5	1.0	4.2	9.0	1.6	.88
ACS	4.3	2.5	16.7	21.4	21.4	21.4	.02[b]
EBL, mean (SD), L	3.7 (3.6)	4.3 (3.6)	0.6 (0.5)	1.9 (2.6)	4.3 (2.9)	0.7 (1.1)	.01[b]

Abbreviations: AAA, abdominal aortic aneurysm; ACS, abdominal compartment syndrome; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CPR, cardiopulmonary resuscitation; CRI, chronic renal insufficiency; EBL, estimated blood loss; EVAR, endovascular aneurysm repair; FFP, fresh-frozen plasma; MI, myocardial infarction; RBC, red blood cell; SBP, systolic blood pressure.

SI conversion factors: To convert hematocrit to proportion of 1.0, multiply by 0.01; and to convert creatinine to micromoles per liter, multiply by 88.4.

[a] Comparing all patients in the preprotocol period with all patients in the postprotocol period.

[b] Statistically significant.

[c] Total number of perioperative blood transfusion units required.

presenting with hypotension had significantly higher 30-day mortality (33.3% vs 10.8%; *P* = .02) and perioperative mortality (37.3% vs 13.5%; *P* = .003) on univariate analysis than did patients not presenting with hypotension. Among hypotensive patients, there was no difference in 30-day mortality based on rAAA type (34.2% for open repair vs 33.3% for rEVAR; *P* > .99) or protocol period (42.9% for preprotocol period vs 22.7% for postprotocol period; *P* = .23). Abdominal compartment syndrome was associated with increased 30-day mortality (54.5% of patients with abdominal compartment syndrome vs 19.5% of patients without; *P* = .05). Three patients (3.4%) died 30 days after surgery but during the index hospitalization (median, 43 days; range, 33-93 days), yielding an overall perioperative/in-hospital mortality rate of 27.7%; *P* = .63).

Morbidity

Of 79 patients surviving initial rAAA repair, 46 (58.2%) had 1 or more major complications (median, 1; range, 0-6), including postoperative death (n = 15), respiratory failure (n = 27), acute renal failure (n = 20), need for dialysis (n = 10), stroke (n = 1), myocardial infarction (n = 7), ischemic colitis (n = 3), limb ischemia (n = 7), or postoperative hemorrhage (n = 5). Significantly fewer patients during the postprotocol period than during the preprotocol period experienced 1 or more major

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Table 2. Perioperative Morbidity and Mortality

Variable	Patients, %						P Value[a]
	Preprotocol			Postprotocol			
	All (n = 46)	Open Repair (n = 40)	EVAR (n = 6)	All (n = 42)	Open Repair (n = 14)	EVAR (n = 28)	
Length of stay, mean (SD), d							
ICU	11.2 (16.6)	11.9 (17.7)	7.2 (8.8)	7.1 (8.8)	8.9 (9.6)	6.1 (8.4)	.17
Total	16.6 (16.8)	18.2 (17.6)	7.8 (8.5)	12.0 (12.1)	16.4 (11.1)	9.9 (12.2)	.15
Complications							
Myocardial infarction	8.9	10.0	0.0	7.1	0.0	10.7	>.99
Acute renal failure	21.7	22.5	16.7	23.8	42.9	14.3	>.99
Need for hemodialysis	11.1	12.5	0.0	12.5	15.4	10.7	>.99
Respiratory failure	34.8	35.0	33.3	26.2	35.7	21.4	.49
Stroke	0.0	0.0	0.0	2.4	0.0	3.6	.48
Hemorrhage	4.4	5.0	0.0	7.1	21.4	0.0	.67
Mesenteric ischemia	2.2	2.5	0.0	4.8	7.1	3.6	.60
Lower extremity ischemia	8.7	7.5	16.7	7.1	14.3	3.6	>.99
Mortality							
Intraoperative	15.2	17.5	0.0	4.8	0.0	7.1	.16
30-Day	32.6	30.0	50.0	14.3	7.1	17.9	.03[b]
In-hospital	37.0	35.0	50.0	16.7	14.3	17.9	.05[b]

Abbreviations: EVAR, endovascular aneurysm repair; ICU, intensive care unit.

[a] Comparing all patients in the preprotocol period with all patients in the postprotocol period.

[b] Statistically significant.

complications (18 of 40 postprotocol patients [45.0%] vs 28 of 39 preprotocol patients [71.8%]; *P* = .02). Similarly, more patients undergoing open repair than undergoing EVAR experienced 1 or more major complications (32 of 46 patients undergoing open repair [69.6%] vs 14 of 32 patients undergoing EVAR [43.8%]; *P* = .04).

Discharge Disposition

The mean ICU and the mean (SD) total hospital length of stay for the preprotocol and postprotocol groups were not significantly different. The mean (SD) ICU length of stay was 11.0 (15.7) days for the open repair group and 6.3 (8.3) days for the rEVAR group (*P* = .11). The mean (SD) total hospital length of stay was longer for the open repair group than for the rEVAR group (17.7 [15.8] days vs 9.5 [11.6] days; *P* = .01). When excluding those patients who did not survive to hospital discharge, there was no significant difference in ICU or total hospital length of stay based on either protocol period or type of rAAA repair.

Sixty-four patients (72.7%) survived to hospital discharge, including 38 of 54 patients (70.4%) after open repair and 26 of 34 patients (76.5%) after rEVAR (*P* = .63). Patients during the postprotocol period were significantly more likely than patients during the preprotocol period to survive to hospital discharge (35 of 42 postprotocol patients [83.3%] vs 29 of 46 preprotocol patients [63.0%]; *P* = .05). In addition, more postprotocol patients than preprotocol patients were discharged to home rather than to a skilled nursing facility (65.7% vs 37.9%; *P* = .04). A significantly higher percentage of patients who underwent rEVAR than open repair were also discharged to home (69.2% vs 42.1%; *P* = .04). Multivariate analysis found rAAA repair during the postprotocol period to be the only independent predictor of discharge to home (odds ratio, 32.8 [95% CI, 1.57-685.00]; *P* = .02) (eTable 2 in the Supplement).

Survival

The median clinical follow-up for those patients who survived to discharge after rAAA repair was 51.9 months (interquartile range [IQR], 10.2-85.7 months) during the preprotocol period and 10.8 months (IQR, 3.1-20.0 months) during the postprotocol period. The median follow-up was 9.3 months (IQR, 2.2-20.1 months) after rEVAR and 34.9 months (IQR, 7.6-66.8 months) after open repair.

The Kaplan-Meier life-table analysis demonstrated that long-term survival was significantly greater after rAAA repair during the postprotocol period than during the preprotocol period (log-rank *P* = .002) (**Figure 2**). This survival advantage was sustained even when excluding those who did not survive to hospital discharge (*P* = .04). Subgroup analysis found both postprotocol EVAR (log-rank *P* = .04) and open repair (log-rank *P* = .01) to be associated with improved long-term survival compared with all patients undergoing repair during the preprotocol period. No significant difference in survival was observed between rAAA repair types during the postprotocol period (log-rank *P* = .27) or based on hypotension at initial presentation (log-rank *P* = .22). A multivariate Cox proportional hazards model with significant univariate inputs identified the postprotocol period as an independent predictor of improved survival rates (hazard ratio, 0.51 [95% CI, 0.25-1.00]; *P* = .05), whereas a history of prior stroke was found to be associated with worse survival during follow-up (hazard ratio, 4.13 [95% CI, 1.35-12.57]; *P* = .01) (eTable 3 in the Supplement).

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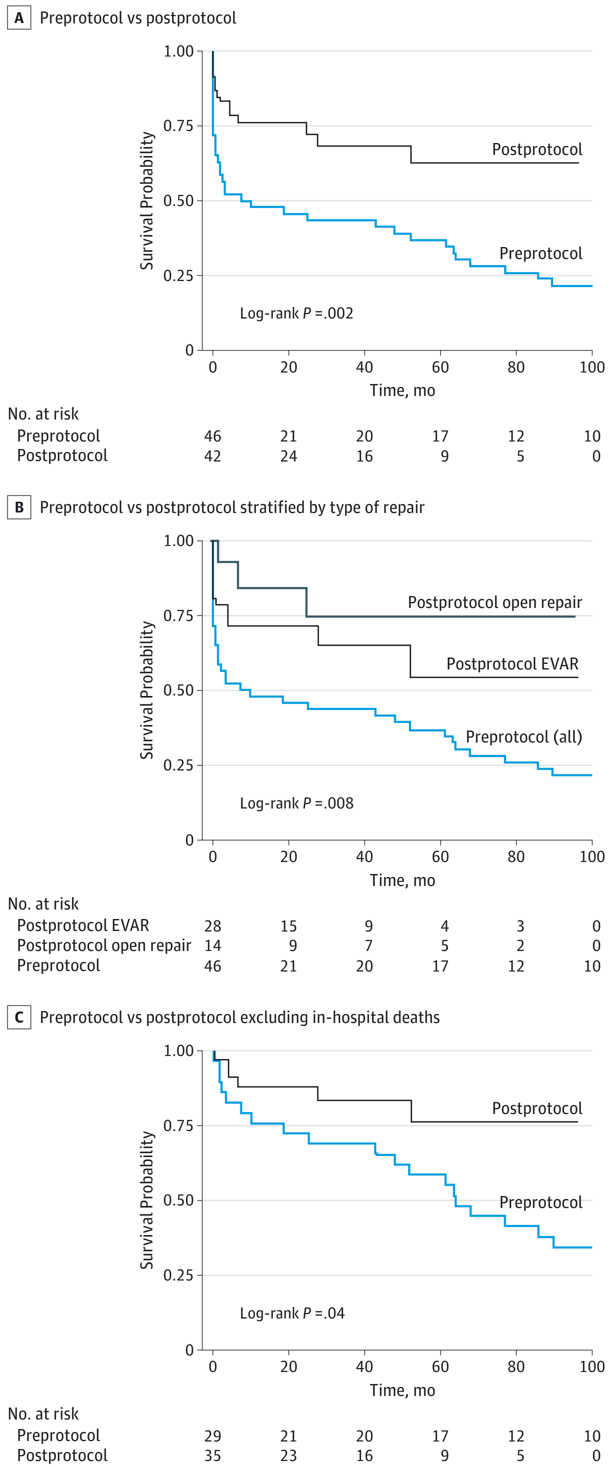
Figure 2. Kaplan-Meier Survival Curves for Preprotocol Period vs Postprotocol Period



B, *P* = .04 for preprotocol (all) vs postprotocol endovascular aneurysm repair (EVAR), *P* = .10 for preprotocol (all) vs postprotocol open repair, and *P* = .27 for postprotocol EVAR vs postprotocol open repair.

Discussion

Despite advances in prehospital medical services, surgical and anesthetic techniques, and critical care medicine, the perioperative mortality rate among patients with an rAAA remains in excess of 40% to 50%, a staggering figure that has gone grossly unchanged over the last half-century. Considering the incidence of rAAAs continues to increase even in the presence of newly developed screening programs and a 100% increase in elective AAA repairs over the last 2 decades,[13] there is great interest in establishing whether the clinical benefit reliably demonstrated for patients undergoing elective EVAR can be translated into the moribund subgroup of patients undergoing rEVAR.

In a recent systematic review and meta-analysis encompassing 18 observational studies, Mastracci and colleagues[14] calculated a pooled mortality of 21% (95% CI, 13%-29%) after rEVAR. They noted that studies reporting the use of algorithms or structured protocols to assess rEVAR eligibility served as a surrogate for a systematic approach to patients with an rAAA and represented an overall indicator of higher quality of care.[14] In fact, the pooled in-hospital mortality rate was 18% (95% CI, 10%-26%) for the 14 studies that detailed an algorithmic approach to rAAAs compared with a mortality rate of 32% (95% CI, 20%-44%) for the remaining studies without such an algorithm.

Our results offer additional support for the clinical benefit of a structured emergency protocol for patients with an rAAA. Since the implementation of our protocol, we observed absolute and relative-risk reductions of 18.3% and 56.2% in 30-day mortality, respectively. We also noted a comparable 20.2% and 54.9% absolute and relative-risk reduction in perioperative/in-hospital mortality, respectively. This significant decrease in early mortality was achieved despite the fact that more than 50% of patients who underwent rEVAR presented with hemodynamic instability in our series, a variable that often precluded an endovascular approach in some earlier experiences. Indeed, the very fact that these unstable patients survived prehospital transport suggests a selection bias owing to increased physiologic reserve. Given the increased early mortality observed among patients presenting with hypotension, we and others[4,15] believe that this select group may yield the greatest benefit of all from an endovascular-first approach.

In addition, we also found the value of our endovascular-first protocol to extend into additional clinical domains, including significant improvements in perioperative morbidity, discharge disposition to home, and long-term survival. The nonsignificant reduction in 30-day mortality for even open repair after implementation of our protocol (1 of 14 preprotocol patients [7.1%] vs 12 of 40 postprotocol patients [30.0%]; *P* = .15) further suggests a positive impact of a structured algorithm in the management of patients with an rAAA, particularly since the mortality rate among those undergoing open repair during the postprotocol period may be reasonably expected to increase as a result of the inherent increased anatomic complexity that made that cohort unsuitable for rEVAR (eg, juxtarenal AAA and tortuous or heavily calcified iliofemoral system). Simi-

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lar to previous studies,[5,7] the implementation of our protocol was associated with significantly more patients being transferred from outside institutions during the more recent time period, a finding that likely confers an additional survival advantage.

Although multiple reports have documented improved survival with rEVAR, we found no significant difference in early mortality based on rAAA treatment type alone, including during the postprotocol period (early mortality rate of 17.9% among patients who underwent rEVAR vs 14.3% among patients who underwent open repair). This lack of significant difference may be the result of a small sample size or the trend toward more free ruptures (42.6% of patients who underwent open repair vs 23.5% of patients who underwent rEVAR; $P = .11$) and less abdominal compartment syndromes (7.4% of patients who underwent open repair vs 20.6% of patients who underwent rEVAR; $P = .10$) among those undergoing open repair. Nevertheless, our lack of mortality difference between rEVAR and open repair reinforces the fact that the clinical benefits demonstrated during the postprotocol period are a reflection of not simply the increased use of rEVAR but, rather, the net effect of complementing the integration of an endovascular-first approach with a more comprehensive structured protocol for patients with an rAAA. Indeed, this assertion is consistent with the previously noted findings by Mastracci et al[14] that such protocols serve as a general indicator of higher quality of care.

Available published structured protocols for the management of patients with an rAAA vary little with regard to their general approach. Prehospital considerations include development of a robust transfer center to aid in early notification to a qualified surgeon, clear and effective communication with the prehospital staff regarding preoperative optimization, and early electronic retrieval of available imaging studies. Hospital considerations include the availability of a 24-hour on-call perioperative/interventional nursing and anesthesia team that is educated regarding both open and endovascular rAAA repair, thereby allowing for the prompt setup of the operating room and the ability of patients transferred from other facilities to bypass the emergency department. Upon arrival to the operating room, we advocate for early restriction of fluids and maintenance of permissive hypotension in order to minimize ongoing hemorrhage and the potential for consumptive coagulopathy. Patients are prepared for surgery while they are still awake, and percutaneous femoral arterial access is obtained, if possible, so as to avoid the vasodilation associated with general anesthesia.

With increasing experience, we have gravitated toward the routine use of expeditious intra-aortic balloons, including during an open repair, as an efficient method to halt an ongoing hemorrhage, minimize the total duration of hemodynamic instability, and provide an opportunity to facilitate early aggressive volume resuscitation. Given the increased mortality associated with abdominal compartment syndrome,[3,10,11,16] a finding corroborated in the present study, our protocol highlights the importance of early recognition of patients at high risk for abdominal compartment syndrome and a correspondingly low threshold for preemptive decompressive laparotomy. Lastly, the importance of ICU care as it relates to aggressive volume resuscitation, judicious early liberation from mechanical ventilation, and management of an open abdomen in the setting of abdominal compartment syndrome cannot be overstated.

The limitations in the present study include the obvious lack of randomization, the modest sample size, the retrospective nature of the data collection, and the inability to control for several perioperative variables (eg, evolving inclusion criteria for rEVAR and intraoperative heparinization). Moreover, although there was no statistical difference in the proportion of juxtarenal/pararenal AAAs before and after implementation of our protocol, the retrospective study design prohibited further detailed analysis between groups regarding the characteristics of the aneurysms, including the actual or anticipated aortic cross-clamp location and the need for visceral or renal artery reimplantation. In addition to the elements featured in the structured protocol, our study extended over a 17-year time period, during which additional advances in perioperative and postoperative management occurred but were unable to be accounted for in this retrospective analysis.

Conclusions

Implementation of a structured endovascular-first emergency protocol for the management of patients with an rAAA is associated with significant improvements with regard to early mortality, perioperative morbidity, discharge disposition to home, and long-term survival. The success of streamlining patient care and achieving an optimal clinical outcome according to such protocols is highly dependent on the continuing education of and the collaborative efforts between a multidisciplinary team composed of emergency medical transport personnel, institutional transfer center personnel, perioperative and interventional suite nursing staff, radiologic technicians, emergency department personnel, anesthesiologists, transfusion services, surgeons, and intensivists.

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