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Routine adjunctive porcine fibrin sealant sac embolization during emergency endovascular repair for ruptured abdominal aortic aneurysm: a before-and-after cohort study

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Abstract

Background

Routine adjunctive sac embolization extends aneurysm sac management beyond endograft exclusion during emergency endovascular aneurysm repair (EVAR) for ruptured abdominal aortic aneurysm (rAAA). We evaluated implementation of this strategy and 30-day outcomes.

Methods

We retrospectively analyzed 31 consecutive patients with rAAA who commenced an emergency EVAR strategy. The historical control group included 14 patients treated between 2019 and 2022; between January 2023 and June 2026, 17 patients underwent routine adjunctive porcine fibrin sealant (PFS) sac embolization. The primary outcome was 30-day postoperative all-cause mortality. We calculated the unadjusted risk difference and its 95% confidence interval.

Results

All 17 patients treated with PFS completed the planned embolization. Several baseline features were less favorable in the PFS era, although Edinburgh score distributions were similar between eras. Thirty-day mortality was 3/17 (17.6%) in the PFS era and 3/14 (21.4%) in the historical era. The unadjusted risk difference was − 3.8 percentage points (95% confidence interval: -32.3 to 23.4). No nontarget embolization was recorded. Two additional rupture-related deaths occurred in the PFS era beyond 30 days.

Conclusions

Routine adjunctive PFS sac embolization was feasible within this center's emergency EVAR workflow. This consecutive rAAA cohort provides a clinical basis for prospective controlled evaluation of the strategy and its perioperative outcomes.

Background

For patients with ruptured abdominal aortic aneurysm (rAAA) with suitable anatomy, emergency endovascular aneurysm repair (EVAR) can control bleeding [1]. Early mortality nevertheless remains substantial in both randomized and registry studies [2, 3]. Stent-graft deployment excludes the aneurysm sac from direct aortic blood flow. However, residual perfusion in the aneurysm sac may cause blood to continue to leak through the damaged aneurysm sac wall [4, 5]. This concern has sparked interest in the treatment of aneurysm sacs during emergency repair. It is not clear whether additional interventions for

aneurysm sacs can improve clinically important outcomes, even when completion angiography shows no visible endoleak.

N-butyl cyanoacrylate (NBCA) has been used for sac or rupture-site embolization during emergency EVAR. Published reports describe treatment of demonstrated sac bleeding, operator-selected embolization, and small series of ruptured aortic or iliac aneurysms [4–6]. These reports provide a procedural precedent for adjunctive sac embolization, although the indications vary. Routine sac embolization with porcine fibrin sealant (PFS), without requiring angiographic evidence of bleeding, raises a different clinical question. Assessing this policy requires documenting who receives the procedure, whether it can be completed, and the outcomes after its adoption.

Our center introduced routine adjunctive PFS sac embolization in 2023. We examined consecutive rAAA cases before and after this change, focusing on implementation and 30-day all-cause mortality. We considered baseline clinical and anatomical differences alongside mortality estimates because changes in case mix can affect an unadjusted comparison. The study evaluates routine implementation in an exclusively rAAA cohort with complete ascertainment of 30-day vital status.

Methods

Study setting and cohort

We conducted a retrospective before-and-after cohort study at a single center, with reporting guided by the STROBE statement [7]. The historical era extended from January 1, 2019, to December 31, 2022. The PFS era extended from January 1, 2023, to June 30, 2026. Follow-up records were updated through August 31, 2026. Patients were classified according to the institutional treatment strategy in effect when emergency EVAR was initiated. Treatment changed at a fixed calendar boundary, so its effects could not be separated from other changes over time (Fig. 1).

Eligible patients had aneurysm rupture confirmed by imaging or operative findings and commenced emergency EVAR during either era. We included all consecutive eligible patients. This EVAR-defined cohort did not represent all patients presenting with rAAA, and excluded those initially managed by open repair. Open conversion, intraoperative death, or failure to complete planned embolization did not constitute grounds for exclusion. The final sample comprised 31 patients. One historical control required open conversion and remained classified according to the initial EVAR strategy.

Consecutive patients with confirmed ruptured abdominal aortic aneurysm who commenced emergency EVAR were classified by treatment era. One historical patient converted to open repair remained in the analysis. Thirty-day vital status was verified in all 31 patients. Treatment strategy and calendar era overlapped completely. EVAR, endovascular aneurysm repair; PFS, porcine fibrin sealant; rAAA, ruptured abdominal aortic aneurysm.

The study was conducted in the Department of Vascular Surgery at The First Hospital of Hebei Medical University, Shijiazhuang, Hebei, China. It was approved by the Clinical Research Ethics Committee of The First Hospital of Hebei Medical University on March 17, 2025 (approval reference: S00274). The ethics review took place at the same hospital. The requirement for informed consent to participate was waived by the committee.

Routine adjunctive sac embolization

Emergency EVAR was performed under general or local anesthesia. In the later era, adjunctive PFS embolization was planned for every included patient, regardless of whether an active endoleak was visible. The target was the abdominal aneurysm sac between the endograft fabric and the aneurysm wall. Demonstration of bleeding from an individual branch was not required. Adequate proximal and distal endograft sealing remained the basis of repair, with sac embolization performed as an additional procedure.

Depending on the anatomical configuration and access route, the catheter was either positioned within the aneurysm sac before stent-graft deployment or advanced into the sac after deployment. Porcine fibrin sealant was used in all 17 patients in the later era. The reported volume is the total volume of sealant administered. The sealant was injected incrementally through the catheter under fluoroscopic guidance. Completion angiography was performed to assess endograft position, sealing, and visible endoleak. Figure 2 shows the stages of surgery for a patient in the PFS group.

Typical angiography sequence of routine adjunctive PFS sac embolization during emergency endovascular aneurysm repair (EVAR) for rupture of abdominal aortic aneurysm. **(A)** Initial aortography before the release of the stent graft shows the aortic segment involved by the aneurysm. **(B)** A fluoroscopic image after the release of the stent graft and before the aneurysm sac embolization. **(C)** Completion aortography after adjunctive sac embolization using porcine fibrin sealant. The images illustrate successive procedural stages.

Measurements and outcome definitions

Clinical records provided demographic characteristics, comorbidities, admission hemodynamics, Glasgow Coma Scale (GCS) scores, laboratory results, and aortoiliac anatomical measurements. Procedural data included anesthesia, aortic balloon occlusion, open conversion, completion of planned embolization, sealant volume, and recorded nontarget embolization. Operative duration, time added by embolization, transfusion requirements, and contrast volume lacked complete, comparable documentation. These resource-use measures were therefore not compared between eras.

The Edinburgh Ruptured Aneurysm Score was reconstructed. One point was assigned for each of GCS < 15, systolic blood pressure < 90 mmHg, and hemoglobin < 90 g/L [8]. Scores ranged from 0 to 3. In both eras, we used the first emergency department GCS assessment, first admission systolic pressure, and

first blood-count hemoglobin. GCS assessment preceded sedation, anesthesia, or intubation. However, none of these admission measurements was assumed to precede all resuscitation. The score analysis was retrospective and exploratory, and the first-admission rule was applied consistently across eras.

The primary outcome is all-cause deaths within 30 days after the implementation of the initial EVAR strategy. We verified 30-day vital status using hospital records and follow-up data. Hospital discharge alone was not considered evidence of 30-day survival. Successful embolization required catheter access to the sac and delivery of the PFS. Other recorded outcome indicators include injection-related technical failure, non-targeted embolism, re-intervention, and intestinal, pelvic, or spinal ischemia within 30 days. The study described the confirmed deaths beyond 30 days separately.

Statistical analysis

Continuous variables, including GCS, were summarized as medians with first and third quartiles. Categorical variables were reported as n/N (%), with variable-specific denominators; missing observations were not treated as normal findings. Exploratory comparisons used two-sided Wilcoxon rank-sum tests or Fisher exact tests. Edinburgh scores were presented by category. One Fisher-Freeman-Halton exact test compared the complete 2 × 4 distribution, without separate tests for individual categories. All three components had to be available to calculate a total score.

Standardized mean differences (SMDs) were used to describe baseline imbalances independently of exploratory P values. For continuous variables, including the Glasgow Coma scale (GCS) score, SMDs were calculated using group means and pooled standard deviations, although the table shows the median. No SMD was calculated for the ordinal Edinburgh score. The numerical size of SMD is not interpreted as the weight of prognosis, and its positive and negative numbers do not uniformly represent whether the clinical differences are favorable or unfavorable. While considering the baseline characteristics, we also paid attention to the mortality rate, and did not construct an unvalidated composite risk score.

Regarding the 30-day mortality rate, we calculated the risk difference (PFS group minus the historical period group) and gave the Newcombe 95% confidence interval (CI); at the same time, we reported the risk ratio and the Katz 95% confidence interval. The sample covers all eligible cases during the study, and the study is not designed to conduct equivalence or non-inferiority testing. In view of the fact that 6 out of 31 patients died and the treatment strategy was completely confounded with calendar era, we did not build a multivariate model or a propensity score model, but retained the unadjusted estimates and their uncertainties, and did not show the adjusted treatment-effect estimate. Analyses were performed using R version 4.6.0.

Results

Clinical and anatomical differences between eras

The cohort included 14 historical controls and 17 PFS-era patients. Several baseline differences favored the historical cohort (Table 1). Median preoperative creatinine was 137.8 versus 67.9 μmol/L in the PFS and historical eras, respectively (available n = 16 and 13; SMD = 1.335; P=.004). White blood cell count was 12.8 versus 8.4 × 10^9/L (SMD = 0.848; P=.034). Coronary artery disease was documented in 6/17 versus 1/14 patients (SMD = 0.733), and median age was 75.0 versus 68.0 years. These differences spanned laboratory and comorbidity measures and were not limited to a single variable.

Table 1
Baseline clinical and anatomical characteristics

Variable	Historical era	n	PFS era	n	SMD	P value
Age, y	68.0 (62.5, 72.8)	14	75.0 (72.0, 78.0)	17	0.380	.141
BMI, kg/m²	24.2 (21.5, 24.8)	13	22.4 (22.0, 24.9)	14	0.217	.645
Admission SBP, mmHg	128.5 (97.0, 148.2)	14	122.0 (101.0, 136.0)	17	-0.110	.751
Shock index	0.7 (0.5, 0.8)	14	0.7 (0.6, 0.8)	17	-0.061	.984
Lactate, mmol/L	1.3 (0.9, 3.4)	9	2.3 (1.6, 2.9)	16	-0.202	.350
pH	7.4 (7.3, 7.4)	9	7.4 (7.3, 7.4)	16	0.454	.533
Preoperative creatinine, μmol/L	67.9 (64.2, 74.7)	13	137.8 (79.7, 163.6)	16	1.335	.004
Hemoglobin, g/L	113.5 (89.8, 123.8)	14	116.0 (96.0, 138.0)	17	0.579	.159
White blood cells, 10^9/L	8.4 (4.9, 14.2)	14	12.8 (10.3, 16.7)	17	0.848	.034
Neutrophils, %	81.8 (70.9, 87.7)	14	87.5 (80.7, 90.0)	17	0.698	.088
Lymphocytes, %	12.4 (4.2, 19.3)	14	6.1 (5.1, 10.0)	17	-0.541	.451
Platelets, 10^9/L	157.0 (138.5, 195.5)	14	167.0 (133.0, 183.0)	17	0.074	.796
Maximum aneurysm diameter, mm	65.0 (50.2, 90.1)	12	72.2 (65.2, 101.9)	14	0.407	.247
Neck diameter, mm	19.2 (17.6, 21.3)	12	21.1 (19.4, 24.8)	14	0.701	.094
Male sex	13/14 (92.9%)	14	15/17 (88.2%)	17	-0.158	1.000
Hypertension	10/14 (71.4%)	14	14/17 (82.4%)	17	0.261	.671
Smoking	4/14 (28.6%)	14	6/17 (35.3%)	17	0.145	1.000
Coronary artery disease	1/14 (7.1%)	14	6/17 (35.3%)	17	0.733	.094
Heart failure	1/14 (7.1%)	14	2/17 (11.8%)	17	0.158	1.000
Diabetes	1/14 (7.1%)	14	3/17 (17.6%)	17	0.323	.607
Preoperative vasopressor use	0/13 (0.0%)	13	2/17 (11.8%)	17	0.516	.492
Preoperative CPR	0/13 (0.0%)	13	0/17 (0.0%)	17	NA	1.000
Preoperative intubation	0/13 (0.0%)	13	0/17 (0.0%)	17	NA	1.000

Variable	Historical era	n	PFS era	n	SMD	P value
Iliac involvement	4/13 (30.8%)	13	10/16 (62.5%)	16	0.671	.139
Admission GCS	14.0 (13.2, 14.0)	14	13.0 (13.0, 14.0)	17	-0.572	.177
Edinburgh score distribution		14		17	NA	.932
Score 0	2/14 (14.3%)	14	2/17 (11.8%)	17	NA	
Score 1	8/14 (57.1%)	14	12/17 (70.6%)	17	NA	
Score 2	2/14 (14.3%)	14	2/17 (11.8%)	17	NA	
Score 3	2/14 (14.3%)	14	1/17 (5.9%)	17	NA	

Values are median (Q1, Q3) or n/N (%); n gives available observations. SMD is PFS minus historical era and uses means for continuous measures, so its sign may differ from the median difference. NA, not applicable or undefined. P values are exploratory and unadjusted for multiplicity (Wilcoxon rank-sum or Fisher exact tests). One Fisher-Freeman-Halton test compares all Edinburgh categories. BMI, body mass index; CPR, cardiopulmonary resuscitation; GCS, Glasgow Coma Scale; SBP, systolic blood pressure; SMD, standardized mean difference.

Aortoiliac anatomical characteristics also differed between eras. Iliac artery involvement was observed in 10/16 PFS-era patients and 4/13 historical controls (SMD = 0.671). The median diameter of the aneurysm neck of the two groups was 21.1 mm and 19.2 mm respectively (available n = 14 and 12, respectively; SMD = 0.701). Neutrophil percentages were higher and lymphocyte percentages were lower in the PFS era. Sufficient admission data were available for all 31 patients. The complete SMD diagram shows a two-way imbalance, including higher hemoglobin concentrations in patients during the PFS application period (Fig. 3).

Signed standardized mean differences (SMDs) are PFS minus historical era, ordered by absolute magnitude. Filled points identify |SMD| ≥0.5 as a visual reference, not a validated threshold for clinical risk. Continuous SMDs were calculated from means and pooled standard deviations; binary SMDs used group proportions. Available sample sizes vary by measure (Table 1). Variables with zero variance in both groups are omitted, leaving 23 displayed variables. No confidence intervals are shown. GCS, Glasgow Coma Scale; PFS, porcine fibrin sealant.

All 31 patients have enough admission records to calculate the Edinburgh score. Median admission GCS was 13.0 (13.0, 14.0) in the PFS era versus 14.0 (13.2, 14.0) in the historical era (SMD=-0.572; P = 0.177). Among the patients in the PFS group, the numbers of patients with Edinburgh scores of 0, 1, 2, and 3 were 2, 12, 2, and 1, respectively; the corresponding numbers of patients in the historical control group were 2, 8, 2, and 2, respectively (overall P = 0.932). The results showed that the distribution of the admission score of the PFS group did not shift towards a high score.

Implementation and perioperative observations

Planned PFS sac embolization was completed in all 17 patients in the later era. The median sealant volume was 20.0 (20.0, 40.0) mL, and there was no non-target embolism. 13 of the 17 patients in the PFS group and 9 of the 14 patients in the historical control group received general anesthesia, and the rest received local anesthesia (P = 0.693). In the two groups, aortic balloon occlusion was used in 3 PFS-era patients and 1 historical control. In the historical control group, one patient was transferred to open surgery, while no patient in the PFS group was transferred to surgery (Table 2).

All 17 patients in the PFS group and 13 patients in the historical control group underwent immediate postoperative angiography examination; only the patient in the historical control group of the transit open surgery did not undergo this examination. In the 30 patients who were examined, no internal leakage was found. The above results only reflect the existing angiography assessment and do not rule out the possibility of postoperative aneurysm sac perfusion.

Table 2
Procedural characteristics and embolization implementation

Variable	**Historical era (n = 14)**	**PFS era (n = 17)**
General anesthesia	9/14 (64.3%)	13/17 (76.5%)
Local anesthesia	5/14 (35.7%)	4/17 (23.5%)
Aortic balloon occlusion	1/14 (7.1%)	3/17 (17.6%)
Conversion to open repair	1/14 (7.1%)	0/17 (0.0%)
Planned PFS embolization completed	NA	17/17 (100.0%)
Total PFS volume, mL	NA	20.0 (20.0, 40.0)
Recorded nontarget embolization	NA	0/17 (0.0%)
Completion angiography performed	13/14 (92.9%)	17/17 (100.0%)
Endoleak on completion angiography	0/13 (0.0%)	0/17 (0.0%)

Values are n/N (%) or median (first quartile, third quartile). Volume refers to the total volume of porcine fibrin sealant administered. NA, not applicable. The historical patient converted to open repair did not undergo completion angiography; the historical endoleak denominator is therefore 13. Zero events indicate no recorded event and do not establish the absence of risk under prospective surveillance.

Thirty-day mortality and later events

In each of the two periods, 3 patients died within 30 days. The mortality rate of the PFS group was 17.6%, and that of the historical control group was 21.4%. The remaining 25 patients were confirmed to be alive after 30 days. The unadjusted risk difference is -3.8 percentage points (95% CI: -32.3 to 23.4). The risk ratio is 0.82 (95% CI: 0.20–3.46), and Fisher's exact test results show that P = 1.000 (Table 3; Fig. 4). Despite the above baseline differences, the mortality point estimates in the two groups were similar. However, the confidence interval was wide.

There was no re-intervention within 30 days after surgery in both periods, and there was no intestinal, pelvic or spinal cord ischemia. Two additional deaths occurred in the PFS era beyond 30 days; both were confirmed to be rupture-related; these two cases were not included in the main endpoint analysis. The arrangements for long-term follow-up and imaging examination in different periods are different, and the cause of death of historical deaths lacks the same standard verification. Therefore, we reported these two late rupture deaths descriptively without estimating comparative late rupture mortality.

Table 3
Mortality and other clinical outcomes

Variable	**Historical era (n = 14)**	**PFS era (n = 17)**
30-day all-cause mortality	3/14 (21.4%)	3/17 (17.6%)
Vital status verified at 30 days	14/14 (100.0%)	17/17 (100.0%)
Recorded reintervention within 30 days	0/14 (0.0%)	0/17 (0.0%)
Recorded bowel ischemia within 30 days	0/14 (0.0%)	0/17 (0.0%)
Recorded pelvic ischemia within 30 days	0/14 (0.0%)	0/17 (0.0%)
Recorded spinal cord ischemia within 30 days	0/14 (0.0%)	0/17 (0.0%)
Verified rupture deaths beyond 30 days	Not comparable	2 observed cases

For 30-day mortality, the unadjusted risk difference (PFS minus historical era) was − 3.8 percentage points (Newcombe 95% CI, − 32.3 to 23.4); the risk ratio was 0.82 (Katz 95% CI, 0.20 to 3.46), with two-sided Fisher exact P = 1.000. Nonfatal outcomes show recorded events over cohort denominators; retrospective ascertainment may be incomplete. The two verified PFS-era rupture deaths occurred beyond 30 days and are excluded from the primary endpoint. Unequal follow-up and historical cause-of-death verification preclude estimation of comparative late rupture mortality. CI, confidence interval.

Mortality was 3/17 (17.6%) in the PFS era and 3/14 (21.4%) in the historical era. The diamond is the risk difference (PFS minus historical era), and the horizontal line is the Newcombe 95% confidence interval based on Wilson score limits. The estimate was − 3.8 percentage points (95% CI, − 32.3 to 23.4). The vertical reference indicates zero difference. This is an unadjusted comparison of treatment eras. CI, confidence interval; PFS, porcine fibrin sealant.

Discussion

Routine adjunctive PFS sac embolization was completed in all 17 patients, demonstrating its feasibility within this center's emergency EVAR workflow. Observed 30-day mortality was 17.6%, compared with 21.4% in the historical control group. This consecutive rAAA cohort documents the implementation of a routine sac-treatment strategy alongside a defined clinical endpoint. Measured baseline differences and calendar-era effects frame the interpretation of the mortality comparison.

The baseline differences warrant consideration because cohorts with different clinical burdens may have similar crude mortality rates. Increased creatinine levels raise concerns about renal vulnerability, while coronary artery disease constitutes another burden of complications. White blood cell counts and the frequency of iliac artery involvement further depict the characteristics of another cohort - the PFS-era cohort was not uniformly more favorable at presentation. One hypothesis is that the improvement of local bleeding control offsets the impact of other clinical adverse factors to a certain extent. Whether adjunctive embolization improves hemostasis remains uncertain, as this outcome was not directly assessed in the present study.

The Edinburgh score analysis helps to define this hypothesis more accurately. The distribution of admission scores of the two groups of patients was similar and did not support describing the PFS group as uniformly more unstable at presentation. The score covers Glasgow coma score (GCS), systolic pressure and hemoglobin indicators, but does not include creatinine, coronary artery disease, white blood cell count or aortoiliac anatomy. Therefore, similar scores do not erase the measured differences, and the differences not covered by the scores are not enough to justify a higher overall risk of death. Some baseline measures, including hemoglobin, were more favorable in the PFS era. A larger median aneurysm neck diameter alone does not establish hostile neck anatomy. In summary, although the later-stage patient group showed adverse characteristics on some measurement indicators, it was not confirmed that there was an increase in their overall risk of death.

Clinical rationale and relation to previous work

Residual sac perfusion or bleeding after stent-graft deployment provides a clinical rationale for adjunctive embolization. Previous reports of NBCA sac embolization provide clinical precedent for adjunctive sac treatment during emergency repair [4–6]. In our protocol, PFS embolization did not depend on identifying a specific bleeding branch or an active completion endoleak. It was intended to supplement exclusion by treating the residual sac space. Changes in sac pressure, immediate blood loss, and subsequent transfusion requirements were not measured consistently. Improved hemorrhage control therefore remains a mechanism to test; it was not an observed mediator of the mortality findings.

In previous studies, there were differences in the selection and treatment sites of patients receiving embolization treatment. Koike et al. performed sac angiography in three patients undergoing emergency EVAR for rAAA, and embolization treatment was carried out on 2 of the patients who were confirmed to

have contrast extravasation [5]. Ohba et al compared 22 embolized patients with seven controls, including both ruptured abdominal aortic and isolated iliac aneurysms [4]. Their operators also treated some patients without visible extravasation, using the rupture site identified on preoperative computed tomography. Mostafa et al subsequently described six patients with ruptured aortoiliac aneurysms who received adjunctive sac embolization [6]. These reports provide precedents for embolization with and without angiographically demonstrated extravasation.

Our contribution is a consecutive, exclusively rAAA cohort spanning a center-level change to routine adjunctive treatment. This extends earlier reports by evaluating routine implementation in a defined rupture population with complete 30-day vital-status ascertainment. Mortality figures from earlier series cannot be directly transferred to this comparison. Ohba et al had a small, older control cohort, and their reported mortality included a control death at three months [4]. Differences in embolic material, patient selection, aneurysm location, and outcome timing prevent these reports and ours from being interpreted as estimates of the same treatment effect.

Uncertainty, procedural burden, and durability

The confidence interval encompassed both potentially important benefit and harm, as well as no effect. A nonsignificant P value does not establish equivalence between the two groups. The treatment strategy coincided with calendar era, so changes in equipment, team experience, resuscitation, or intensive care may have accompanied the adoption of embolization. The distribution of general and local anesthesia also differed numerically. These factors may have influenced outcomes independently of PFS, and their net effects were not measured. With six deaths, multivariable adjustment would likely yield unstable estimates.

Completion in all 17 patients indicates that the additional step was achievable within this center's emergency workflow. It does not establish the absence of a procedural cost. Sac embolization requires catheter manipulation and controlled delivery of the embolic material. No nontarget embolization or early bowel, pelvic, or spinal cord ischemia was recorded in this cohort. The sample was too small to characterize uncommon harms. Incomplete data on added time, transfusion, and contrast exposure also prevent a balanced estimate of the burden of routine use.

Two subsequent deaths from ruptured abdominal aortic aneurysms involved another dimension of the strategy. Both cases occurred outside the main outcome observation period. Available records did not establish the mechanism of either late rupture or a causal relationship with the initial embolization procedure. Nevertheless, these cases show that even if the aneurysm sac embolization is successfully completed, it cannot ensure that the rupture can be prevented for a long time. Therefore, after undergoing endovascular aneurysm repair (EVAR), it is still crucial to ensure reliable proximal and distal closure and continued imaging surveillance [1].

Study limitations and next steps

Consecutive inclusion reduced discretionary exclusions within the EVAR-treated cohort, but it does not eliminate selection bias associated with EVAR eligibility, nor does it cover all patients with aneurysm rupture. Some laboratory examinations and anatomical indicators are missing. In addition, the inconsistency of long-term follow-up time further limits the scope of application of the conclusion, making it mainly limited to the 30-day clinical endpoint with complete data records.

A prospective study using a control of the same period can not only verify the hypothesis of benefits, but also record the cost of increasing embolization operations. A unified standard should be used to record the patient's physiological state and kidney, heart and anatomical characteristics at the time of admission. Record the demand for blood transfusion, the time of additional operation and the amount of contrast agent exposure. Standardized imaging follow-up can link early clinical outcomes with long-term aneurysm sac changes and re-intervention. This will help clarify the mechanism of the strategy.

Conclusions

Routine adjunctive PFS sac embolization was completed in all 17 patients treated during the later era, supporting its feasibility within this center's emergency EVAR workflow. Thirty-day mortality was 17.6% in the PFS era and 21.4% in the historical era. The consecutive rAAA cohort and complete 30-day vital-status ascertainment provide a clinical basis for prospective controlled evaluation of routine sac embolization.

Declarations

Ethics approval and consent to participate

This study was approved by the Clinical Research Ethics Committee of The First Hospital of Hebei Medical University on March 17, 2025 (approval reference: S00274). The requirement for informed consent to participate was waived by the committee.

Consent for publication

Written informed consent for publication of the Fig. 2 patient images was obtained.

Competing interests

The authors declare that they have no competing interests.

Use of artificial intelligence

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Author Contribution

LHZ: Conceptualization, Investigation, Writing – review & editing. ZL: Conceptualization, Formal analysis, Writing – original draft. PL: Investigation, Data curation. XL: Data curation. YZ: Data curation, Supervision. LZ: Investigation, Supervision. All authors reviewed the manuscript and approved its submission. LHZ denotes Lihua Zheng and LZ denotes Lei Zhang

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Not applicable.

Data Availability

The de-identified data supporting the conclusions of this study are available from Zexu Lu (luzexu2021@163.com) upon reasonable request, subject to protection of patient privacy and any necessary institutional approvals.

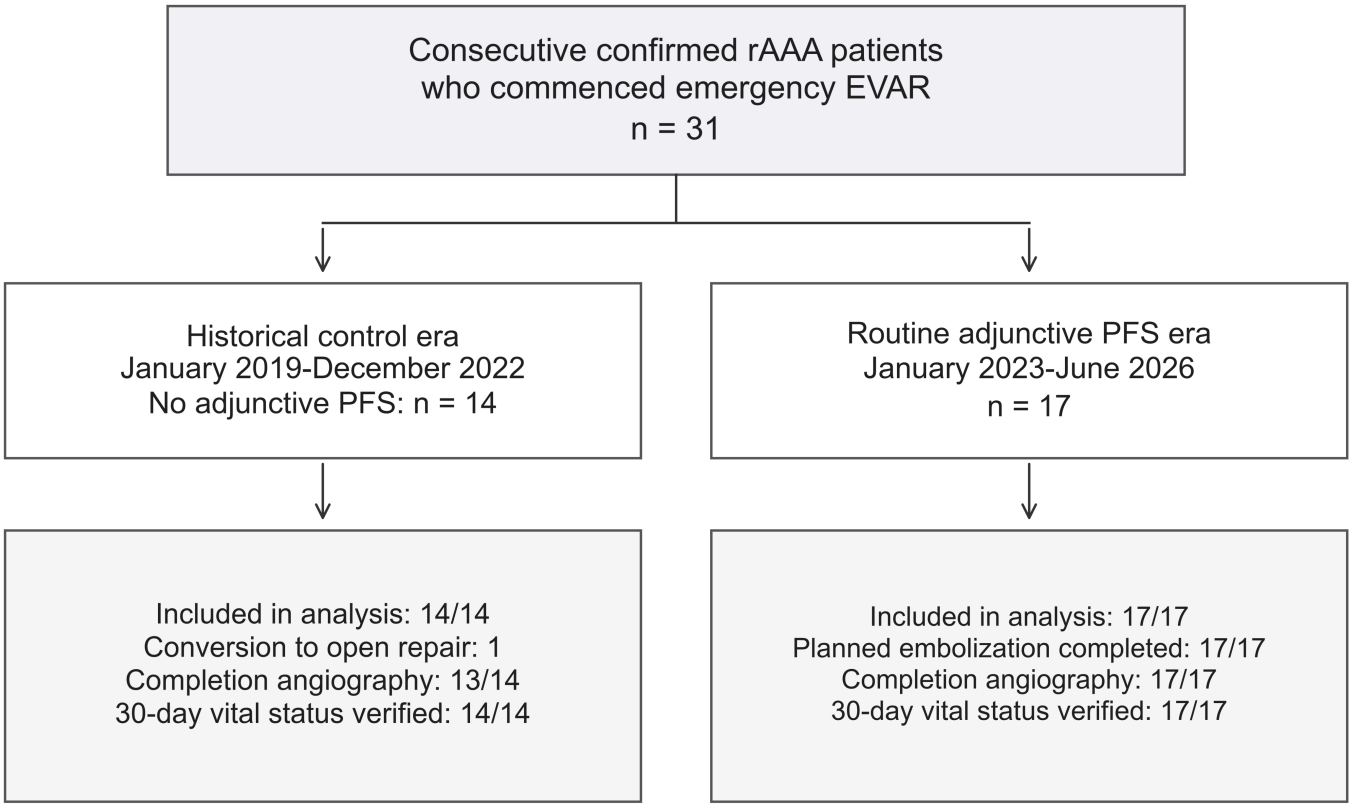
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Figures



Treatment strategy and calendar era overlapped completely

Figure 1

Study cohort and treatment eras

Consecutive patients with confirmed ruptured abdominal aortic aneurysm who commenced emergency EVAR were classified by treatment era. One historical patient converted to open repair remained in the analysis. Thirty-day vital status was verified in all 31 patients. Treatment strategy and calendar era overlapped completely. EVAR, endovascular aneurysm repair; PFS, porcine fibrin sealant; rAAA, ruptured abdominal aortic aneurysm.

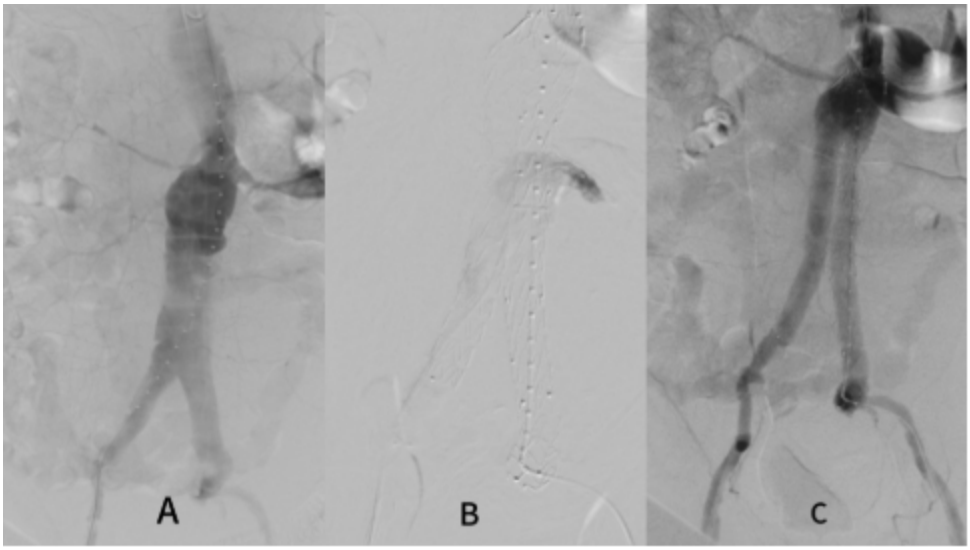


Figure 2

Intraoperative images of adjunctive sac embolization

Typical angiography sequence of routine adjunctive PFS sac embolization during emergency endovascular aneurysm repair (EVAR) for rupture of abdominal aortic aneurysm. **(A)** Initial aortography before the release of the stent graft shows the aortic segment involved by the aneurysm. **(B)** A fluoroscopic image after the release of the stent graft and before the aneurysm sac embolization. **(C)** Completion aortography after adjunctive sac embolization using porcine fibrin sealant. The images illustrate successive procedural stages.

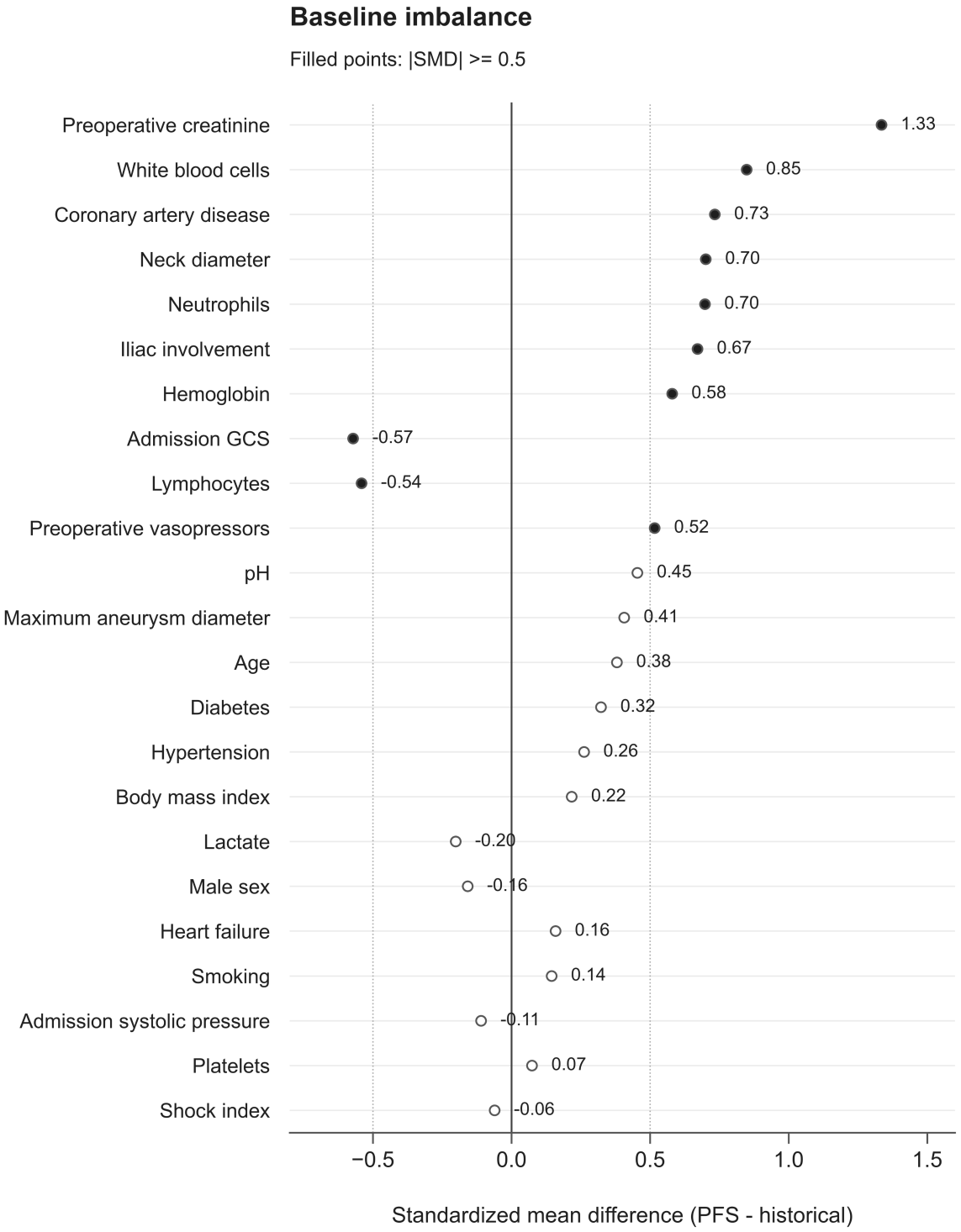


Figure 3

Baseline differences between treatment eras

Signed standardized mean differences (SMDs) are PFS minus historical era, ordered by absolute magnitude. Filled points identify |SMD| ≥0.5 as a visual reference, not a validated threshold for clinical risk. Continuous SMDs were calculated from means and pooled standard deviations; binary SMDs used

group proportions. Available sample sizes vary by measure (Table 1). Variables with zero variance in both groups are omitted, leaving 23 displayed variables. No confidence intervals are shown. GCS, Glasgow Coma Scale; PFS, porcine fibrin sealant.

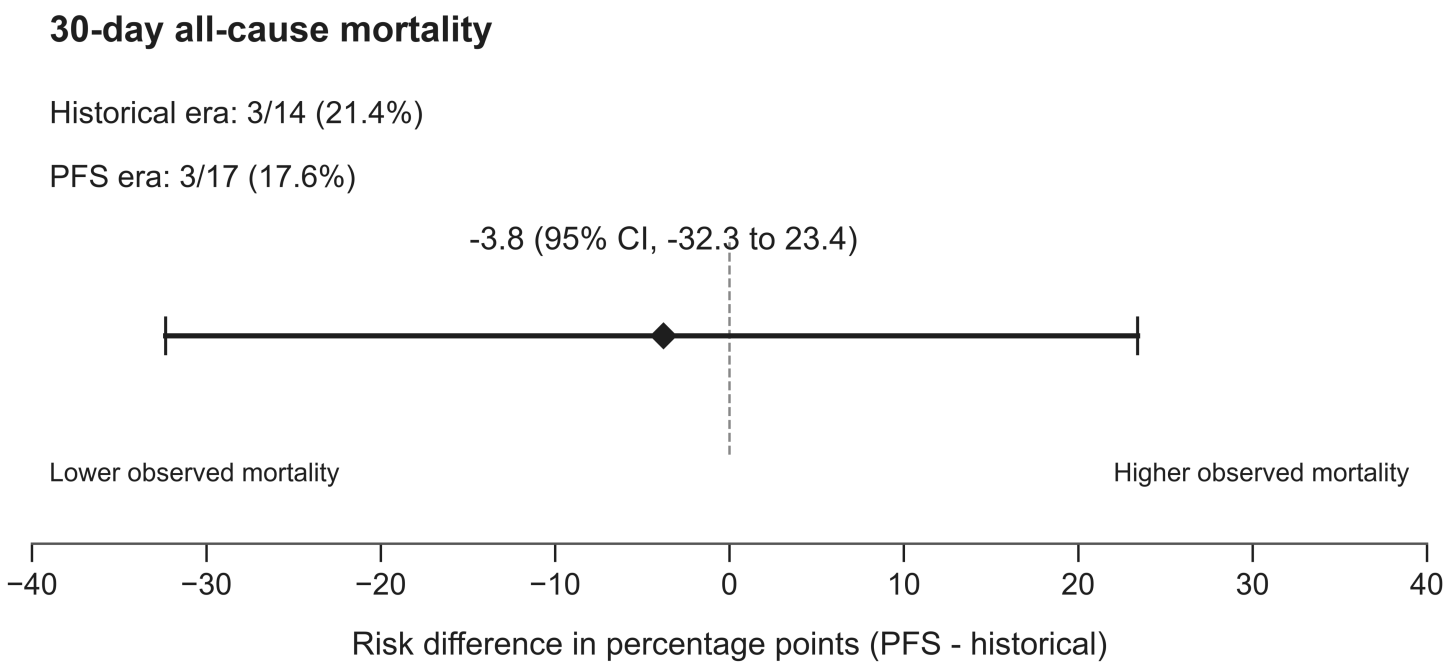


Figure 4

Unadjusted difference in 30-day all-cause mortality

Mortality was 3/17 (17.6%) in the PFS era and 3/14 (21.4%) in the historical era. The diamond is the risk difference (PFS minus historical era), and the horizontal line is the Newcombe 95% confidence interval based on Wilson score limits. The estimate was −3.8 percentage points (95% CI, −32.3 to 23.4). The vertical reference indicates zero difference. This is an unadjusted comparison of treatment eras. CI, confidence interval; PFS, porcine fibrin sealant.