Twenty-four-hour emergency intervention versus early intervention in aneurysmal subarachnoid hemorrhage

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OBJECTIVE Recent observational data suggest that ultra-early treatment of ruptured aneurysms prevents rebleeding, thus improving clinical outcomes. However, advances in critical care management of patients with ruptured aneurysms may reduce the rate of rebleeding in comparison with earlier trials, such as the International Cooperative Study on the Timing of Aneurysm Surgery. The objective of the present study was to determine if an ultra-early aneurysm repair protocol will or will not significantly reduce the number of incidents of rebleeding following aneurysmal subarachnoid hemorrhage (SAH).

METHODS A retrospective analysis of data from a prospectively collected cohort of patients with SAH was performed. Rebleeding was diagnosed as new or expanded hemorrhage on CT, which was determined by independent review conducted by multiple physicians. Preventability of rebleeding by ultra-early aneurysm clipping or coiling was also independently reviewed. Standard statistics were used to determine statistically significant differences between the demographic characteristics of those with rebleeding compared with those without.

RESULTS Of 317 patients with aneurysmal SAH, 24 (7.6%, 95% CI 4.7–10.5) experienced rebleeding at any time point following initial aneurysm rupture. Only 1/24 (4.2%, 95% CI –3.8 to 12.2) incidents of rebleeding could have been prevented by a 24-hour ultra-early aneurysm repair protocol. The other 23 incidents could not have been prevented for the following reasons: rebleeding prior to admission to the authors' institution (14/23, 60.9%); initial diagnostic angiography negative for aneurysm (4/23, 17.4%); postoperative rebleeding (2/23, 8.7%); patient unable to undergo operation due to medical instability (2/23, 8.7%); intraoperative rebleeding (1/23, 4.3%).

CONCLUSIONS At a single tertiary academic center, the overall rebleeding rate was 7.6% (95% CI 4.7–10.5) for those presenting with ruptured aneurysms. Implementation of a 24-hour ultra-early aneurysm repair protocol would only result in, at most, a 0.3% (95% CI –0.3 to 0.9) reduction in the incidence of rebleeding.

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KEY WORDS cerebral aneurysm; rebleeding; ruptured aneurysm; subarachnoid hemorrhage; vascular disorders

FOLLOWING aneurysm rupture, current guidelines call for repair of the aneurysm via surgical clipping or endovascular coiling “as early as possible.”² Nonetheless, the optimal time to repair a ruptured aneurysm remains uncertain, and some authors advocate a protocol of 24-hour emergency treatment as a way to reduce morbidity and mortality due to aneurysmal rebleeding. The underlying premise of such an assertion is that the rebleeding rate in the current paradigm of early treatment (within 24 hours of presentation) is substantial, leading to

significant morbidity and mortality that could be avoided by offering treatment immediately following presentation. In a single-center observational study, Park et al. report a much higher incidence of rebleeding in historical controls when treatment was offered within 72 hours after rebleeding, as opposed to more recent patients who were treated immediately following admission (7.4% vs 2.1%; $p = 0.003$).¹² This prevention of rebleeding led to much better outcomes for the immediate-treatment group (modified Rankin Scale Score 0–3; 87.9% vs 79.7%; $p = 0.008$).

ABBREVIATIONS CTA = CT angiography; MRA = MR angiography; NICU = neurological intensive care unit; OR = operating room; SAH = subarachnoid hemorrhage; WFNS = World Federation of Neurosurgical Societies.

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Thus, those authors suggest that changing subarachnoid hemorrhage (SAH) systems of care to offer immediate aneurysm treatment would lead to significant improvement in clinical outcomes.

The rebleeding rate in Park et al. is similar to that reported by the International Cooperative Study on the Timing of Aneurysm Surgery, which revealed that the rebleeding rate was 4.5% within the first 24 hours and then 14.5% over the next 13 days.^{6,12} However, the frequency with which rebleeding occurs overnight in patients receiving appropriate neurological intensive care management is unknown. Advances in critical care management, such as strict blood pressure control, pain management, nausea and emesis prevention, reversal of coagulopathies, and admission to a dedicated neurological intensive care unit (NICU) may reduce the rate of aneurysmal rebleeding prior to treatment, and thus negate any benefit observed with ultra-early treatment. At our institution, clipping or coiling of the aneurysm is performed within 24 hours of hospital admission in all stable patients. However, clipping or coiling is not generally performed outside regular operating room (OR) hours, and patients presenting overnight are managed in the NICU until the following morning, when definitive aneurysm repair is performed. We hypothesized that the incidence of rebleeding in patients with ruptured aneurysms managed overnight in a modern NICU prior to clipping or coiling is low, and therefore institution of a 24-hour immediate aneurysm treatment protocol would lead to very little reduction in the overall rate of rebleeding at our institution.

Methods

Study Design

This is a retrospective analysis of data from a prospectively collected cohort of patients with SAH. Data were obtained prospectively by physicians and supplemented with retrospectively gathered data from electronic medical records. Approval for this study was obtained from our institutional review board, and the board gave a waiver of informed consent for this retrospective study.

Patient Population

All patients with aneurysmal SAH admitted to our NICU between January 2010 and March 2014 were included in the patient registry used for this study. Criteria for a diagnosis of SAH for this registry have been previously described.¹⁵ Patients with spontaneous SAHs that were not due to ruptured aneurysm, as confirmed by angiography, were not included in the current study.

Clinical Care

All patients were treated according to the current guidelines established by the Neurocritical Care Society and American Heart Association.^{2,3} A multidisciplinary team of neurosurgeons and neurointensivists in a dedicated NICU provided care for these patients. In the case of a ruptured aneurysm, patients received the standard institutional protocol that included 24-hour emergency diagnostic angiography and 24-hour access to CT angiography (CTA) and CT perfusion. Patients generally under-

go microsurgical clipping or endovascular coiling of the ruptured aneurysm within 24 hours; however, emergency overnight repair is not typically performed unless clinically indicated for patients presenting with ruptured aneurysms resulting in space-occupying hemorrhages requiring immediate evacuation. Patients presenting overnight receive emergency diagnostic angiography and are subsequently admitted to the NICU, where their blood pressure is tightly controlled to maintain systolic blood pressures < 140 mm Hg, their pain and fever are treated, and they receive neurological assessments at least hourly. Signs of hydrocephalus are treated with the placement of an external ventriculostomy, and the ventriculostomy is drained for pressures > 20 cm H₂O. Nimodipine at a dose of 60 mg every 4 hours is given to all patients, and alterations in dosages are made for those who become hypotensive. Patients with angiogram-negative SAH receive a repeat conventional angiogram 7–10 days after the initial angiogram. Additionally, all patients with nontraumatic SAH undergo either CTA or MR angiography (MRA), and a contrast-enhanced MRI study of the brain and cervical spine is performed in all angiogram-negative cases.

Clinical Data

The method for obtaining prospectively gathered clinical data has been previously described.¹⁵ Prospectively gathered data included presence of rebleeding, age, sex, history of hypertension, history of coronary artery disease, smoking status, alcohol use, location of aneurysm, size of aneurysm (mm³), Hunt and Hess grade, modified Fisher Scale grade, World Federation of Neurosurgical Societies (WFNS) SAH grade, Hijdra sum score for SAH, time of symptom onset, time of diagnosis, time of rebleeding, and presence of intracranial hemorrhage.

Data gathered retrospectively included time of admission to the emergency department and time of operation. The charts and CT scans of all patients underwent additional independent review to confirm the presence or absence of rebleeding. An occurrence of rebleeding was diagnosed by the presence of new or expanded hemorrhage on CT. Two board-certified neurointensivists who were not involved in the surgical care of patients independently reviewed each incidence of rebleeding, and determined whether the rebleeding could have been prevented by ultra-early aneurysm repair. In all occurrences that could not have been prevented, they identified a specific, objective reason why that was the case. For all incidents of rebleeding, the reviewers were unanimous in their decisions about whether it was preventable.

Statistical Analysis

To compare the differences between the demographic and clinical characteristics of those with and without rebleeding, chi-square or Fisher exact tests were used for categorical variables and the t-test was used for continuous variables, as appropriate. We considered a 2-sided p value < 0.05 as statistically significant. Demographic analysis was completed using SPSS software (IBM SPSS Statistics for Windows, version 23.0) and SAS software, version 9.4 (SAS Institute).

TABLE 1. Demographic and clinical information in 317 patients with SAH

Variable	Patients w/ No Rebleeding, n = 293	Patients w/ Rebleeding, n = 24	p Value
Age in yrs, mean $\pm$ SD	56.4 $\pm$ 13.6	58.7 $\pm$ 14.8	0.43
Sex			0.72
Female	209 (71.3%)	18 (75.0%)	
Male	84 (28.7%)	6 (25.0%)	
Hypertension	158 (53.9%)	13 (54.2%)	0.98
Coronary artery disease	22 (7.5%)	7 (29.2%)	0.003
Tobacco use	156 (53.2%)	6 (25.0%)	0.01
Alcohol use	38 (13.0%)	0 (0.0%)	0.09
Aneurysm location			0.76
Anterior	241 (82.3%)	18 (75.0%)	
Posterior	45 (15.4%)	4 (16.7%)	
Aneurysm size in mm ³ , mean $\pm$ SD	6.7 $\pm$ 4.4	5.8 $\pm$ 4.0	0.12
Hunt & Hess grade			0.004
1	26 (8.9%)	0 (0.0%)	
2	96 (32.8%)	3 (12.5%)	
3	68 (23.2%)	4 (16.7%)	
4	58 (19.8%)	13 (54.2%)	
5	45 (15.4%)	4 (16.7%)	
Modified Fisher grade			0.72
1	34 (11.6%)	1 (4.2%)	
2	11 (3.8%)	1 (4.2%)	
3	178 (60.8%)	18 (75.0%)	
4	64 (21.8%)	4 (16.7%)	
WFNS grade			<0.001
1	101 (34.5%)	1 (4.2%)	
2	71 (24.2%)	3 (12.5%)	
3	20 (6.8%)	2 (8.3%)	
4	50 (17.1%)	14 (58.3%)	
5	51 (17.4%)	4 (16.7%)	
Hijdra SAH sum score, mean $\pm$ SD	21.2 $\pm$ 10.5	25.2 $\pm$ 9.4	0.03
Time btwn onset of Sx & diagnosis in hrs, mean $\pm$ SD	13.2 $\pm$ 19.3	7.5 $\pm$ 5.0	0.19
Time btwn onset of Sx & ED admission in hrs, mean $\pm$ SD	13.9 $\pm$ 19.9	8.7 $\pm$ 5.9	0.24
Time btwn onset of Sx & op in hrs, mean $\pm$ SD	28.2 $\pm$ 24.0	20.1 $\pm$ 12.0	0.37
Intracranial hemorrhage	69 (23.5%)	11 (45.8%)	0.02

ED = emergency department; Sx = symptoms.

Results

Demographic and clinical data comparing patients who had an occurrence of rebleeding following an initial SAH with those who did not have subsequent rebleeding following an SAH are described in Table 1. Patients with a previous medical history of coronary artery disease ($p = 0.003$) or smoking ($p = 0.01$) were significantly more likely to develop rebleeding. An SAH with a higher Hunt and Hess grade ($p = 0.004$), WFNS grade ($p < 0.001$), or Hijdra SAH sum score (21.2 vs 25.2; $p = 0.03$) were also associated with rebleeding. In addition, the presence of intracranial hemorrhage was associated with rebleeding ($p = 0.02$). However, the other measured variables did not demonstrate a statistically significant difference between

those patients with an occurrence of rebleeding compared with those without one. Of the 287 patients who were transferred on an emergency basis to our institution from an outside hospital, 21 (7.3%; 95% CI 4.3–10.3) had rebleeding, compared with the 3 cases of rebleeding (10.0%; 95% CI –0.7 to 20.7) that occurred in the 30 patients who did not transfer ($p = 0.49$).

Of the 317 patients who presented with aneurysmal SAH, 24 (7.6%; 95% CI 4.7–10.5) had an incidence of rebleeding at any time point following initial aneurysm rupture. Only 1 of the 24 (4.2%; 95% CI –3.8 to 12.2) occurrences of rebleeding could potentially have been prevented with a 24-hour ultra-early aneurysm repair protocol (Table 2). That patient had a large hemorrhage in the basal ganglia that was initially thought to be hypertensive

TABLE 2. Details about 24 patients with rebleeding of an SAH

Age (yrs)	Sex	Aneurysm Location	Size (mm ³)	Hunt & Hess Grade	Modified Fisher Grade	Preventable by Emergency Intervention?	Clinical Summary
55	F	ICA	4.8	IV	4	Yes, if aneurysm immediately recognized	Admitted w/ a large lt-sided basal ganglia hemorrhage w/ interventricular extension, thought to be consistent w/ hypertensive bleeding. No vessel imaging. Subsequent angiogram, obtained following rebleeding, confirmed the aneurysm.
51	F	ACoA	3	V	4	No	Ruptured during coiling attempt on PBD 1 at outside hospital & subsequently transferred.
48	F	Perical-losal	2	III	3	No	Coiling attempted at outside hospital; CT on arrival showed new ACA territory IPH due to A ₂ aneurysm.
63	M	ACoA	2	IV	3	No	Underwent clipping of ACoA aneurysm, followed by clinical vasospasm & subsequent rebleeding.
59	F	Perical-losal	4.9	IV	3	No	CT on arrival showed expansion of intraparenchymal clot compared to CT at outside hospital.
86	F	ICA	2	II	1	No	Initial diagnostic angiogram showed no clear saccular aneurysm. Rebleeding occurred 7 days later, which showed fusiform supraclinoid lt ICA aneurysm & lt ICA saccular component.
51	M	MCA	12	II	3	No	Taken to OR; case aborted due to hypoxia secondary to severe COPD, neurogenic pulmonary edema, & mucus plugging.
71	F	None identified		IV	3	No	Rebleeding present on CT on arrival, appeared to occur during transit (patient could not be flown in due to inclement weather).
45	F	PICA	3	II	3	No	Angiogram believed to be negative, but after rebleeding a suspected PICA lesion was noted. Explored via suboccipital craniotomy w/ PICA aneurysm clipping.
80	M	MCA	9.3	IV	3	No	Decompensated after CT at outside hospital & intubated. Initial CT on arrival showed significant increase in hemorrhage size.
43	F	MCA	3.7	IV	3	No	Transferred from outside hospital. Initial CT showed that IPH had increased in size.
71	M	Basilar trunk	5	IV	3	No	Admitted w/ SAH due to a fusiform BA aneurysm status after surgery for mitral valve prolapse. Not a candidate for immediate intervention due to cardiovascular instability. Developed rebleeding on PBD 2.
62	F	PICA	3	V	2	No	Initial angiogram negative. On PBD 3, CT showed an increase in interventricular blood products. Repeat angiogram showed small PICA aneurysm that was subsequently clipped.
69	F	ICA		IV	4	No	New IPH on initial head CT compared to CT from outside hospital.
61	F	ICA	8	V	4	No	Presented to outside hospital w/ small intracerebral hemorrhage. Subsequently transferred to 2nd hospital, where she developed worsening neurological Sx; CT showed significant hemorrhage expansion.
63	F	PCoA	9	IV	3	No	Interval increase in IPH btwn initial head CT and CTA at outside hospital.
53	F	Tip of BA	4	III	3	No	Presented w/ perimesencephalic distribution SAH, w/ P ₁ & rt MCA aneurysms. Underwent coiling of P ₁ aneurysm, then experienced an abrupt spike in intracerebral pressure. CT showed rebleeding associated w/ rt MCA aneurysm, which was subsequently coiled.
36	F	PCoA	10	III	3	No	Experienced mild increase in bleeding on post-coil CT, w/ report of extravasation noted during procedure.
72	M	None identified		III	3	No	Initial MRA showed possible basilar tip aneurysm but VA angiography was negative. Significant posterior fossae rebleeding on PBD 6, w/ MRA again negative for obvious aneurysm.
81	M	ACoA	5	IV	3	No	Increase in size of lt frontal IPH w/ mild increase in intraventricular hemorrhage on CT obtained immediately after arrival following transfer from outside hospital.
49	F	PCoA	3	V	3	No	CT from outside hospital not available; on arrival, hematoma size had clearly expanded per H&P documents.
23	F	MCA	18	IV	3	No	Unsuccessful coil attempt at outside hospital; CT showed rebleeding on arrival.
51	F	ACoA	6	IV	3	No	Anterior gyrus rectus hematoma had doubled in size on arrival compared w/ initial head CT.

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TABLE 2. Details about 24 patients with rebleeding of an SAH

Age (yrs)	Sex	Aneurysm Location	Size (mm ³)	Hunt & Hess Grade	Modified Fisher Grade	Preventable by Emergency Intervention?	Clinical Summary
65	F	PCoA	4	IV	3	No	Patient deteriorated during transfer from outside hospital. On arrival, she was immediately taken to OR for decompressive craniectomy & aneurysm clipping; no CT obtained prior to op. Postop CT showed significant increase in Lt IPH consistent w/ interval rebleeding, probably prior to arrival.

ACA = anterior cerebral artery; ACoA = anterior communicating artery; BA = basilar artery; COPD = chronic obstructive pulmonary disease; H&P = history & physical examination; ICA = internal carotid artery; IPH = intraparenchymal hemorrhage; MCA = middle cerebral artery; PBD = postbleed day; PCoA = posterior communicating artery; PICA = posterior inferior communicating artery; VA = vertebral artery.

in origin. As a result, diagnostic angiography was not completed on an emergency basis, as is the usual protocol. The rebleeding occurred in the NICU overnight, 8 hours after initial presentation, where it was immediately recognized due to a surge in blood pressure and intracranial pressure, accompanied by bloody ventriculostomy output. Subsequent diagnostic angiography confirmed the presence of an aneurysm adjacent to the hematoma. If the aneurysm had been immediately recognized and treated with surgical clipping or endovascular coiling, the rebleeding could potentially have been prevented.

The remaining 23 of 24 (95.8%) incidents of rebleeding would not have been prevented with a 24-hour ultra-early aneurysm repair protocol (Table 3). Fourteen of the 23 (60.9%) patients had rebleeding prior to arriving at our institution from the outside hospital where they initially presented. Four of the 23 (17.4%) patients underwent diagnostic angiography, which did not reveal a cerebral aneurysm. Each of these patients experienced rebleeding prior to undergoing a repeat cerebral angiogram at approximately 7 days, per our institutional protocol. Two (8.7%) patients developed rebleeding postoperatively. One of them had clinical vasospasm with subsequent rebleeding. The other patient presented with 2 aneurysms. The first aneurysm was coiled, but postoperatively rebleeding was noted and the second aneurysm was then coiled. Two (8.7%) patients were unable to tolerate an operative procedure due to medical instability. The first was taken to the OR, but the procedure was aborted shortly after anesthesia induction due to refractory hypoxia secondary to severe chronic obstructive pulmonary disease, neurogenic pulmonary edema, and mucus plugging. The second patient had recently undergone surgery for mitral valve prolapse and experienced cardiovascular instability, including hypotension and bradycardia requiring emergency transvenous pacing. One of the 23 (4.3%) patients had intraoperative rebleeding. Aside from the 1 patient described in detail above, no others experienced rebleeding while admitted to the NICU overnight prior to undergoing clipping or coiling during regular OR hours.

Discussion

We report on 24 patients with rebleeding following hospital admission for ruptured cerebral aneurysm, lead-

ing to a 7.6% (95% CI 4.7–10.5) overall rebleeding rate over a 5-year period. Fourteen of the 24 (58.3%) incidents of rebleeding occurred prior to the patient's transfer to our institution and so could not have been prevented by a 24-hour ultra-early treatment protocol. Such a protocol would not have prevented rebleeding in another 9 patients for several reasons, including initially negative results on diagnostic angiography, inability to tolerate treatment due to medical instability, or postoperative rebleeding. Only 1 of the 24 (4.2%; 95% CI –3.8 to 12.2) occurrences of rebleeding could potentially have been prevented by a 24-hour ultra-early treatment paradigm protocol, if the patient's intracerebral hemorrhage had been recognized as due to an underlying aneurysm and if that aneurysm had been immediately secured. This would have resulted in an overall reduction by 0.3% (95% CI –0.3 to 0.9) in the rebleeding rate at our institution.

Whereas data from Park et al. suggest that immediate treatment of aneurysms in patients with SAH will lead to better outcomes,¹² we have shown that at our center, only 1 patient's incidence of rebleeding could possibly have been prevented by ultra-early treatment, and then only if the bleeding had been immediately recognized as aneurysmal rather than hypertensive. Park et al. compared outcomes and rebleeding rates between a more recent period when aneurysms were repaired immediately (including overnight if that was when the patient presented), and a period several years prior when repair was performed between 0 and 72 hours after presentation. In the earlier comparison period, clipping was performed a median of 39.7 hours

TABLE 3. Incidents of rebleeding in 23 patients that were not preventable with the 24-hour emergency aneurysm repair protocol

Type of Rebleeding	No. of Patients (%)
Rebleeding prior to arrival at our institution	14 (60.9)
No aneurysm identified on initial angiogram	4 (17.4)
Rebleeding that developed postop	2 (8.7)
Unable to perform op due to medical comorbidities	2 (8.7)
Intraop rebleeding	1 (4.3)

after admission, and coiling was performed a median of 49.4 hours after admission. This is in contrast to the practice at our institution, where aneurysms are repaired within 24 hours, but emergency overnight repair is not typically performed. The significant benefit of implementing an emergency aneurysm repair protocol in Park et al. may simply be due to the larger delay until treatment in the comparison group. Additionally, although they attempted to account for confounding by using propensity scores, the comparison group all received care several years before the emergency treatment group. Consequently, confounding due to treatment-by-period effects, particularly due to changes in ICU management, may also account for the difference between their results and those noted in the current study.

Current SAH systems of care within the US advocate early treatment of ruptured cerebral aneurysms, although the optimal treatment timing is unclear.^{1,4,5,9,11,13,14} Although a protocol of 24-hour ultra-early aneurysm treatment has theoretical benefits, it also is not without significant cost. Clinical teams specializing in cerebrovascular care consist of proceduralists, anesthesiologists, nurses, interventional radiology technologists, and critical care nurses. There would be significant cost in keeping such highly specialized teams available 24 hours a day. Use of such teams at off hours would prevent the same team from performing elective procedures and thus result in a lack of efficiency and the need for multiple teams. A mandate of 24-hour ultra-early aneurysm treatment in an era of cost-efficient medical care may lead to the establishment of off-hour clinical teams without significant specialization.^{7,8,10} On the other hand, the current paradigm of early treatment allows patients to be stabilized during off hours, with treatment being performed during daytime hours. This allows for the treatment team to be productive with elective surgical work, because their time and endurance is not being drained after hours.

In our experience, only 1 patient (0.3%; 95% CI –0.3 to 0.9) experienced rebleeding after admission and before treatment. With such a low percentage of patients experiencing rebleeding prior to treatment, our current protocol for treating patients with SAH within 24 hours of presentation is likely to be superior to immediate treatment, because the extremely small reduction in the overall rate of rebleeding would probably be counteracted by increased cost, provider fatigue, and possibly increased complications due to the fact that less experienced and less specialized OR and interventional radiology staff are available overnight.

Of the 317 patients who presented with an SAH, 14 (4.4%) incidents of rebleeding were in transferred patients who had experienced rebleeding prior to arriving at our institution. This 4.4% rebleeding rate matches the 4.5% rebleeding rate within 24 hours of admission reported by the International Cooperative Study on the Timing of Aneurysm Surgery.⁶ When we evaluated patients who presented with SAH directly to our institution, none experienced rebleeding within the 24 hours prior to treatment. Thus, this raises questions regarding the critical care management provided to patients with SAH who are being transferred, and may represent an area for improvement. It would be of

value to combine data from large-volume centers to understand the rebleeding rate of ruptured aneurysms in patients who are not transferred from outside hospitals.

Our study suffers from many of the limitations and biases that are typical of observational studies with a retrospective component. Clinical data were largely collected prospectively, and the presence of rebleeding was confirmed by an additional secondary review to ensure accuracy. However, there is no objective test to determine if rebleeding may have been preventable, so it was necessary to rely on the independent clinical review of 2 neurointensivists. Fortunately, virtually all of the rebleeding occurrences had unambiguous reasons why they would not have been prevented by ultra-early treatment (rebleeding occurred before admission, aneurysm was not detected prior to rebleeding, or the patient was too unstable to undergo intervention). The reviewers erred on the side of caution in labeling rebleeding as preventable if ultra-early intervention could have prevented it in any possible way, and were unanimous in their decisions.

Additionally, because data were derived from a single center, these results may not generalize to other centers. In particular, the vast majority of patients with SAH who are admitted to our institution are transferred from outside hospitals, and these patients may be more likely to experience rebleeding prior to admission. Although our cohort is relatively sizable, the inclusion of additional subjects from multiple high-volume institutions would improve the strength of our conclusions and should be the subject of follow-up studies.

Conclusions

At a single tertiary academic center, the overall rebleeding rate was 7.6% for those presenting with ruptured aneurysms. Implementation of a 24-hour ultra-early aneurysm repair protocol would have only resulted in a 0.3% reduction in the incidence of rebleeding. Further study at additional high-volume centers is necessary to confirm the generalizability of these findings. However, these results suggest that the benefit of ultra-early aneurysm repair may be outweighed by the additional risks and costs of emergency overnight aneurysm clipping or coiling.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Pandey. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: Linzey, Williamson. Critically revising the article: Pandey, Williamson. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Pandey. Study supervision: Pandey, Thompson.

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