

# Systematic Review of Endovascular, Surgical, and Conservative Options for Infectious Intracranial Aneurysms and Cardiac Considerations

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*Introduction:* With rising rates of intravenous drug use, Infectious Intracranial aneurysms (IIAs) are a relevant topic for investigation. We performed a systematic review to better understand current practice patterns and limits of current published literature. *Method:* 131 publications with a total of 499 patients (665 aneurysms) were included. Of the 499 patients, 83 were single case reports, and 20.5% of the total had multiple aneurysms. 35.8% of all aneurysms were ruptured. Of those reporting treatment, options included conservative antibiotic therapy (30.0%), open surgical intervention (31.1%), and endovascular occlusion (31.8%). Chronologically, publication of IIAs has increased. Usage of endovascular therapies has grown, while conservative and surgical management have declined in the literature. Overall, 56.2% of aneurysms for which conservative therapy was initiated eventually either underwent intervention or death of patient occurred. *Results:* The issue of cardiac valve surgery in relationship to aneurysm therapy was discussed in 20.8% (80 patients) of all 384 infectious endocarditis patients; of which 15.0% (12) underwent valve surgery before aneurysm treatment and 85.0 patients (68)% underwent valve surgery after aneurysm treatment. For 51 of the patients where valve surgery followed aneurysm management, the corresponding aneurysm treatment modality could be determined; 58.8% (30) of whom were managed endovascularly. 32.7% (26) of all cases reporting cardiac surgery details underwent cardiac surgery during their admission with the IIA. *Conclusions:* Overall, increasing trend of endovascular management of IIAs is evident, and a strong temporal preference exhibited by providers to perform cardiac surgery subsequently to IIA management.

**Key Words:** Infectious intracranial aneurysms—mycotic aneurysms—systematic review—management—endovascular—surgical

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## Introduction

Intracranial infectious aneurysms (IIAs), or mycotic aneurysms as commonly referred to, are a rare subtype of

intracranial aneurysm. IIAs are found in 5%-12% of infective endocarditis (IE) patients with neurological manifestations.<sup>1</sup> Thus with the increasing rate of intravenous drug abuse in rural communities<sup>2</sup> and incidence of admissions of IE nationally,<sup>3</sup> the complication of the mycotic aneurysm is becoming ever more important in cerebrovascular disease.

The pathogenesis of IIAs in the setting of IE is thought to occur via hematogenous spread. The cerebral vessels are initially seeded with bacteria via septic emboli and it is theorized the infection accesses the outer adventitial wall via the vaso vasorum. The infection then progresses inward toward the lumen, and destruction of vessel wall components occur, including the internal elastic lamina. The result is structural weakening and increased susceptibility to the continuous hydrostatic blood pressure, and thus aneurysm growth.<sup>4</sup> Because of the embolic mechanism of spread, IIAs occur in multiplicity, and are more

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Received September 26, 2018; revision received November 23, 2018; accepted November 30, 2018.

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1052-3057/\$ - see front matter

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<https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.11.035>

common in distal cerebral vessels. In contrast in a secondary mechanism of formation, direct extravascular invasion by bacterial can occur, often in the setting of meningitis and other parameningeal infections, resulting in aneurysm formation at vessel locations near meningeal layers.<sup>5</sup>

There is a lack of a consensus regarding management of IIAs. IIAs tend to be thin-walled and friable, often with wide necks, making them prone to rupture.<sup>5</sup> Conservative therapy with prolonged antibiotics is often utilized for unruptured aneurysms. Open surgical techniques such as aneurysm resection, parent artery trapping/occlusion with or without bypass and clipping are all options for ruptured IIAs and/or presence of concurrent large hematoma.<sup>6</sup> However, the aneurysm's friable nature and poorly defined neck tends to make clipping a precarious and technically challenging feat.<sup>4</sup> Endovascular techniques utilized for IIAs include direct embolization with glue agents, parent artery occlusion and stent coiling. These techniques may be advantageous for deeper surgically inaccessible aneurysms and cases with multiple aneurysms.

In addition to the IIA management itself, providers must evaluate aneurysm treatment in the context of the systemic management of the patient. There is no clear consensus on balancing aneurysm treatment decisions against surgical treatment of an infected cardiac valve. While ruptured mycotic aneurysms often require immediate treatment, for unruptured aneurysms, questions persist regarding the order of procedures. Is it better to treat the aneurysm and then perform valve repair/replacement, or vice-versa? Delaying valve surgery poses the risk of cardiac insufficiency, however, an uncontrolled aneurysm in the setting of perioperative factors of cardiac bypass, including systemic heparinization, has its own dangers.<sup>7</sup>

It is evident from the many clinical factors to be deliberated and absence of a standardized treatment algorithm, IIA patients may be treated with a high degree of variation spanning over time and institutions. To better understand practice paradigms and limits of current published literature, we performed a systematic review of IIA management including cardiac surgery considerations.

## Methods

We performed a comprehensive literature search using Pubmed. The terms "Infectious Intracranial Aneurysm," "mycotic cerebral aneurysm," "cerebral mycotic aneurysm," and "intracranial infectious aneurysm" were searched. We retrieved all English language publications from January 1980 to May 2017 where patients' clinical data could be delineated with regards to IIA characteristics, treatment modality, and clinical course. Both single patient case reports and case series were included. Publications which consisted of patients obtained from

searching large nationwide patient databases were excluded due to the risk of including duplicate patients reported in other retrieved publications.<sup>8</sup> We included all non-English publications where sufficient clinical data was provided in an English-language abstract. Manual search of references from retrieved publications and other literature reviews was also performed. The study adhered to the PRISMA guidelines.

One hundred and thirty one total publications detailing 499 patients were retrieved. We quantitated aneurysm number, ruptured status, mention of IE, treatment modality utilized, conservative management outcomes including need for further intervention, rupture or death, and cardiac surgery timing relative to aneurysm management. Placement into treatment and outcomes categories were based on specifically the aneurysm being considered rather than the corresponding patient due to the existence of patients with multiple aneurysms treated via different methods. All data acquisition was performed by a single independent investigator with preoutlined spreadsheet before any data interpretation was performed. The principal summary measure is percentage of the aneurysms or patients corresponding to a treatment category of the total cumulative aneurysms/patients retrieved and eligible for each specific category. We did not conduct bias risk assessment of each individual publication as each study contained inherent bias due to its publication nature. Publication bias exists in the form of preferential reporting of novel interventions and cases by institutions and authors.

## Results

### *Literature Summary*

The annual quantity of case reports and case series regarding IIAs retrieved via search of pubmed using above mentioned search terms, as well as extensive search of references of retrieved articles, has grown in recent years (Fig 1). Overall 131 publications detailing 499 unique patient cases and 665 aneurysms were retrieved between 1980 and May 2017. Table 1 represents a summary of the characteristics of IIAs reported in the literature. Of these, 35.8% were explicitly reported as ruptured at presentation. From reported case details, it was determined whether final aneurysm management was via conservative, open surgical, or endovascular methods, which amounted to 30.1%, 31.1%, and 31.7%, respectively. Of the subjects in the 83 single patient case reports, 20.5% had multiple aneurysms.

### *Management*

The number of aneurysms finally managed via each of the modalities of conservative methods, open surgical methods, and endovascular methods was summated for

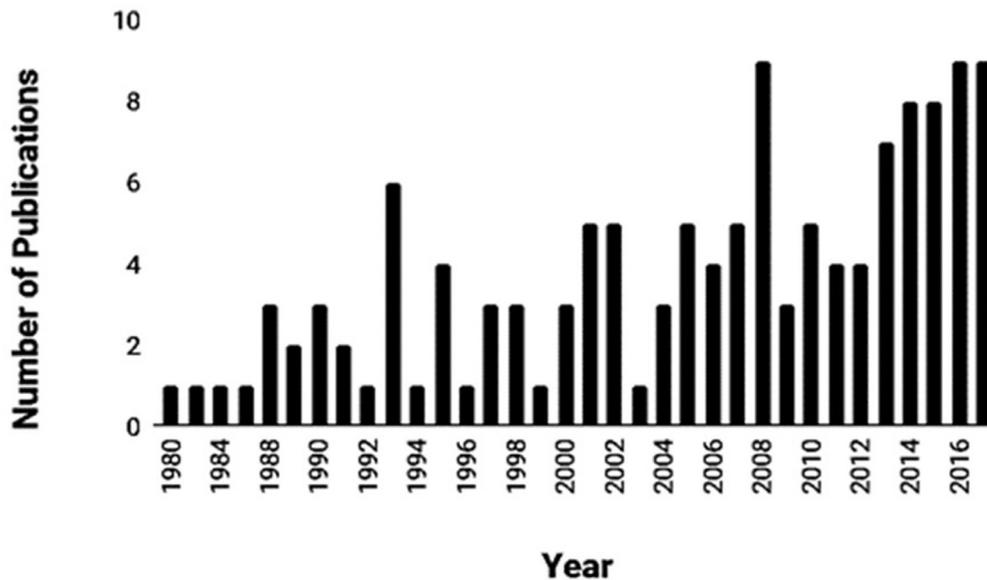


Figure 1. Annual publications by chronology.

each year from 1980 to 2017 and it is evident there is an increasing trend toward endovascular management (Fig 2).

Table 1. Literature summary

Year range of publication	1980-2017
Number of publications	131
Number of patients	499
Total aneurysms	665
IAs reported as ruptured(% of all aneurysms)	238 (35.8)
Treated conservatively (%)*	200 (30.1)
Treated by open surgical method (% of all IAs)*	207 (31.1)
Treated by endovascular method (% of all IAs)*	211 (31.7)
Number of single patient case reports	83
Single patient case reports reporting multiple aneurysms (% of single patient case reports)	17 (20.5)
Aneurysms initially treated conservatively followed by intervention or death of patient (% of all aneurysms initially treated conservatively)	177 aneurysms (56.2)
Aneurysms ruptured during conservative therapy (% of all aneurysms treated conservatively)	31 aneurysms (9.8)
Aneurysms for which patient death occurred during conservative therapy (% of all aneurysms treated conservatively)	38 aneurysms (12.1)

\*Treatment of remaining IAs was not explicitly reported.

Table 1 outlines notable conservative management outcomes. Among aneurysms reported as initially conservatively treated, 56.2% (173 aneurysms) eventually resulted in death of the patient or underwent definitive treatment. More specifically, 9.8% (N = 31) of aneurysms undergoing conservative therapy ruptured during treatment, while death of the corresponding patient occurred in 12.1% (38) of these aneurysms. Death was most commonly due to aneurysm rupture/hemorrhage.<sup>9-14</sup> Table 2 outlines the details regarding cardiac surgery in relation to aneurysm management. While valve surgery details were only discussed in 20.8% (80 patients) of 384 IE patients, the majority (84.9% [68]) underwent cardiac surgery after the aneurysm was managed.

Table 2 outlines the details regarding cardiac surgery in relation to aneurysm management. Valve surgery details were only discussed in 20.8% of the 384 IE patients (80 patients), 84.9% of which underwent cardiac surgery after the aneurysm was managed (68 patients). Of these 68 patients, the initial aneurysm treatment modality for 51 of the patients could be determined, revealing that 58.8% (30 patients) had been treated via endovascular management.

## Discussion

### Conservative Therapy

The proportion of conservatively managed cases reported in the literature has decreased in recent times. The data regarding conservative management shows significant rate of progression to requiring definitive aneurysm intervention or death of the patient. This “failure rate” we have obtained likely overstates the inefficacy of conservative treatment, because there were cases in which a decision to intervene occurred within days of beginning

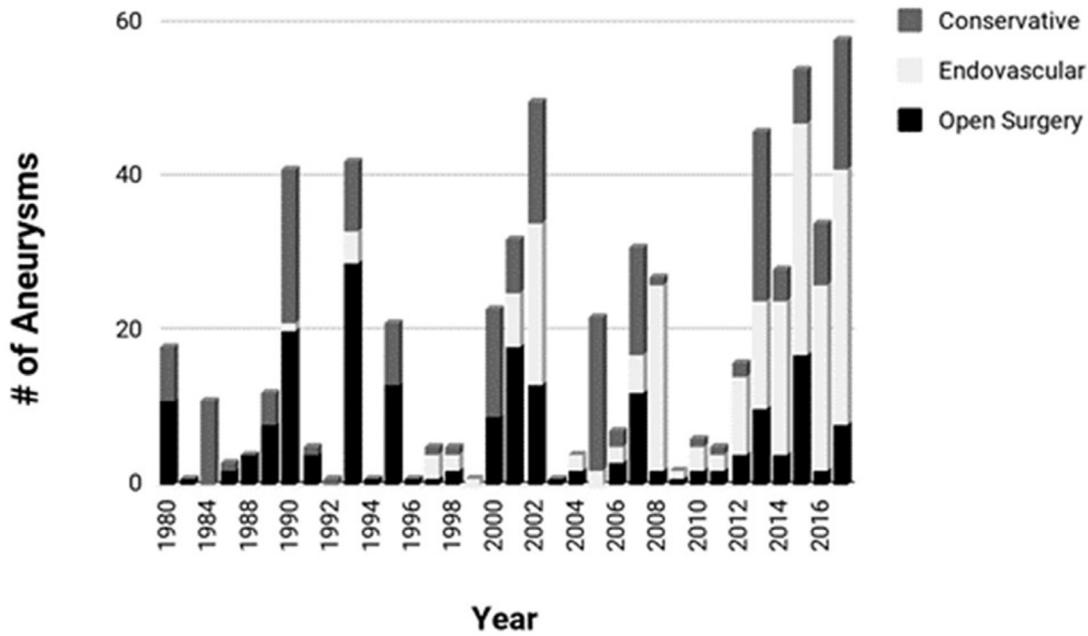


Figure 2. Aneurysm treatment modality volume by chronology.

a trial of antibiotic therapy alone. One large series demonstrated a mean time of 37.7 days +/- 16 days until resolution.<sup>4</sup> Due to an existing risk of rupture, enlargement and persistence, conservatively managed patients should be closely followed with regular imaging.<sup>4,15</sup> Furthermore, there is likely a publication bias toward intervention since successful conservative management alone would not likely represent a publishable topic. Our data is congruent with other published studies. A 2015 retrospective review of the nationwide inpatient sample infers similar negative

conclusions about conservative management.<sup>8</sup> The paper reports a mortality of 26% for those who underwent conservative therapy versus 15% for patients having undergone intervention. Evidently, conservative therapy can be associated with significant risks for hemorrhage and death. However, it is also important to account for the potential for selection bias by the treating physician when considering mortality data of conservative management, especially as cohorts were not randomized. It is possible that healthier patients with greater likelihood for good recovery were preferentially selected for aggressive intervention.

Table 2. Cardiac surgery detail # of patients (%)

Overall # cases due to IE etiology	384 (77.0)
Patients whom valve surgery details were reported (% of IE patients)	80 (20.8)
Patients undergoing cardiac surgery prior to IIA management (% of reported cardiac cases)	12 (15.0)
Patients undergoing IIA management prior to cardiac surgery (% of reported cardiac cases)	68 (84.9)
Patients who underwent IIA management prior to cardiac surgery and the corresponding IIA management was endovascular modality (% of all patients who underwent IIA management prior to cardiac surgery and corresponding IIA management modality could be determined (51 patients))	30 (58.8)
Patients reported as undergoing cardiac surgery during admission for aneurysm (% of reported cardiac cases)	26 (33.0)

IE, infective endocarditis.

### Surgical Therapy

The friable walls and often wide-necked structure of IIAs make them prone to rupture<sup>5</sup> and contribute to the increased difficulty of certain surgical techniques such as clipping.<sup>4</sup> Thus, when open surgery is employed, resection of aneurysm is often undertaken with parent vessel sacrifice.<sup>15</sup> Fittingly, like conservative management, the rate of open surgical management of IIAs reported has recently been decreasing. In our review of all open surgical cases in the literature, 4 of the 6 reportings of failed surgical attempts were scenarios where the aneurysm could not be localized upon craniotomy after being visualized on preoperative angiography.<sup>16-19</sup> Additionally, there was 1 report of cardiac arrest during induction of anesthesia,<sup>20</sup> 1 death from cerebellar infarction during clipping,<sup>21</sup> and 1 death after clipping of an m2 aneurysm due to progressive bleeding from lenticulostriate arteries.<sup>22</sup> Thus, open surgery on IE patients with mycotic aneurysms carries risks associated with both the aneurysm itself and

with the morbidities associated with the patient population. Therefore, careful patient selection along with use of technology such as frameless neuronavigation is important to optimize outcome.<sup>23</sup>

### *Endovascular Therapy*

Endovascular techniques provide an advantage for surgically inaccessible aneurysms and multiple aneurysms. Furthermore, anesthetic time may be shorter for an endovascular procedure, which can be an important consideration in patients with endocarditis and cardiac valvular insufficiency. The surge in endovascular management of IIAs as demonstrated in our review is likely in large part due to advancements in endovascular technology and devices, including coils with improved maneuverability and ability to conform to the contours of the aneurysm, leading to quicker interventions with reduced risk for iatrogenic ruptures.<sup>24</sup> Additionally, the distal locations of most IIAs make parent vessel obliteration using modern embolization agents a safe and reasonable treatment, which can be completed endovascularly without cortical dissection often needed in open surgical procedures. Regarding proximal IIAs, the effectiveness of flow diversion has been demonstrated, which can exclude the aneurysm while preserving the parent vessel.<sup>25</sup> Although some providers may be hesitant to implant permanent devices due to the theoretical risk of device infection in a bacteremic patient, our literature review did not discover any such reported cases. However, endovascular interventions are not always performed without difficulty or other adverse events. In the literature there were 5 unsuccessful attempts of endovascular therapy,<sup>4,17,26,27</sup> and 3 deaths following endovascular intervention; 1 due to thromboembolic complications<sup>28</sup> and 2 due to bleeding within 48 hours.<sup>29</sup> These notable risks may be a reflection of the unstable and friable nature of the cerebrovascular system in these patients.

### *Cardiac Surgery*

Management decisions regarding timing of cardiac in surgery in relation to aneurysm management are complicated but require careful consideration. The opposing approaches are to perform cardiac surgery before or after aneurysm management. In our review, we found details regarding cardiac surgery timing were only reported in 20.8% of the cases. However, the rate of reporting may not be greatly discrepant from the actual proportion of IIA patients who undergo cardiac surgery. Singla's study of the Nationwide Inpatient Sample database of 393 IIA patients demonstrated only 72 patients (18.3%) underwent cardiac surgery during their hospitalization.<sup>8</sup> To our knowledge, our literature review is the first to quantitate the rate at which one temporal sequence is preferred over the other in regards to IIA management and cardiac surgery. 15.0% of all reported underwent cardiac surgery

before aneurysm management, while 85.0% underwent cardiac surgery after the aneurysm was controlled. The former poses the associated neurological risks of cardiac bypass in the presence of an uncontrolled aneurysm, including perioperative heparinization, systemic hypotension, and potential cerebral edema. Additionally, the possible need for postoperative anticoagulation maintenance complicates the management in cases of IIA. However, opting to perform cardiac surgery after presents the heightened risk of cardiac insufficiency when undergoing general anesthesia for aneurysm surgery in patients with poor valve function. Another issue is that a waiting period after craniotomy for ruptured IIA is suggested before cardiac surgery is undertaken due to the need for perioperative anticoagulation during cardiac surgery.<sup>7</sup> The 85% tendency to manage aneurysms first, as demonstrated in our review, is likely indicative that providers often deem an uncontrolled aneurysm in the setting of cardiac surgery and high risk for intracranial hemorrhage much less acceptable. In these cases where providers have opted for cardiac surgery after aneurysm management, the preferred method of intervention appears to be endovascular. In our review of 51 patients who had cardiac surgery second and the initial method of aneurysm intervention could be determined, 58.8% (30 patients) underwent endovascular management. The relatively increased appearance of the endovascular-cardiac surgery combination may be due to the advantage that cardiac surgery can be performed with less delay after endovascular intervention for aneurysm. This is likely due to the lack of restrictions on heparinization after endovascular management, versus the often-recommended delay in anticoagulation after a craniotomy for surgical treatment. This concept is supported by recent literature, as a 2017 single institution retrospective review demonstrated that 8 of 9 consecutive patients who had open heart surgery within a week of endovascular aneurysm management had good outcomes.<sup>30</sup> Indeed 5 of these patients' aneurysms were unruptured but still embolized for the purpose of promoting safe open heart surgery and anticoagulation. Overall the evidently low rate of cardiac valve surgery during the IIA admission (32.7%) may be representative of institutions' hesitancy to manage both conditions in proximity. If the treatment approach of utilizing endovascular management followed by same-admission cardiac surgery is further validated with positive clinical outcomes, it may promote a paradigm where a greater proportion of IIAs are managed endovascularly. Clearly, this issue requires further study.

### **Limitations**

The chronologically increasing number of IIA cases reported in the literature implies a potential increase in incidence. At the very least, providers are focusing more

closely on this disease, suggesting a more voluminous role in their practice. In the current climate of epidemic intravenous drug abuse in regions throughout the United States<sup>2</sup> and increasing rates of IE,<sup>3</sup> this developing interest is logical as the literature reflects the growing problem. However, as this report is a review of publications rather than epidemiologic data-based incidence, the association is only implied. Another limitation was the nonuniformity of data reported. There were several data elements we attempted to capture in the review but were forced to abandon because they were so rarely reported among the literature in any consistent fashion. These included such elements as intravenous (IV) drug use patterns, recidivism, quantitative outcome scores, and cardiac valve surgery details. IV drug use and the rate of recidivism after aneurysm management could be a factor that impacts treatment decisions. The decision to invasively manage an aneurysm and leave a device implanted in the patient, which may theoretically act as a nidus for infection, needs stronger support and study in a patient who uses IV drugs after aneurysm management. Thus, our review demonstrates a need for reporting these elements in future prospective studies. Further details regarding cardiac valve surgery timing are additional crucial elements that require investigation. Such details were only reported in 20% of all cases in our review. However, 77% of the patients were reported to have IE; thus, many would have had cardiac valve pathology, and likely surgical management at some point. It is likely the cardiac surgery course of patients with IIAs is under-reported due to a lack of appreciation of its importance on IIA treatment decision-making. Another possibility is that follow-up intervals after IIA treatment in the literature were not extended enough to incorporate the cardiac valve surgery as an endpoint. Future publications should set out to consistently report details regarding cardiac surgery timing and any adverse effects which arise from comanagement of aneurysms.

The data we present reports a high degree of poor clinical outcomes from conservative management ranging from aneurysm rupture or death, which poses the question whether a more aggressive approach should be standard for patients presenting with IIA. Many publications only advocate for intervention for IIAs in certain circumstances: (1) rupture, (2) symptomatic presentation, or (3) non-resolution or growth of aneurysm despite a trial of 1-2 weeks of antibiotic therapy.<sup>5</sup> However, the increased tendency of IIAs to rupture may support more proactive invasive aneurysm management even in unruptured cases. Alternative strategies have been put forth such as using aneurysm size thresholds to determine need for intervention; it has been suggested that aneurysms >10 mm often rupture when treated medically.<sup>16</sup> Additionally a recent case series included in our review demonstrated a significant size difference in IIAs which respond to antibiotics (4.1 +/- 2.2 mm) compared to

unresponsive IIAs (7.5 +/- 3.1 mm) ( $P = .01$ ).<sup>4</sup> Other experienced providers have suggested that intervention should be performed whenever the IIA is accessible, in part due to a weak correlation between size and rupture tendencies.<sup>9,18</sup> The risks associated with invasive procedures may very well be outweighed by the potential benefit of avoiding catastrophic outcomes when considered on a large patient population scale. The limits of the literature prevent us from assessing the validity of this hypothesis as there is inconsistent reporting of a quantitative outcome for each treatment modality. Future publications regarding management of IIAs should aim to subject each patient to a specific quantitative outcome scoring scale, such as the Modified Rankin Score. This would plausibly allow for direct comparison of the incidence of adverse effects of various invasive procedures, and whether they are still favorable compared to the rates of negative outcomes in conservative management. Such data would allow providers to make an informed decision in the management of IIA patients at currently ambiguous treatment pathways.

As the publications included in our review are all of a retrospective nature, there is a high potential for bias. A large factor to consider is that institutions and authors are likely to describe a series of cases highlighting novel treatment scenarios and methods, while not publishing standard or "typical" management cases. This may have contributed to the increasing rate of endovascularly managed cases, as endovascular intervention continues to evolve with novel tools and innovative techniques. However, the implied increase in endovascular treatment remains likely, as it is consistent with overall trends in general aneurysm treatment volumes toward endovascular interventions.

## Conclusions

Presently there is a lack of validated consensus regarding clinical decisions surrounding IIA management despite the increasing publications reporting the pathology in recent times. Over the previous 2 decades there has been a progressive increase in endovascular management, and it is not the predominant method utilized in the literature. Our literature summary should inspire conversation as to whether a more aggressive paradigm is necessary when providers are confronted with this patient population. It is also evident that cardiac surgery after aneurysm management rather than before is strongly favored, and most often follows endovascular management. There is a need for further investigation to develop systems of practice for outcome optimization.

## Supplementary Materials

Supplementary data to this article can be found online at [doi:10.1016/j.jstrokecerebrovasdis.2018.11.035](https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.11.035).

## References

- Royden Jones H, Siekert RG. NEUROLOGICAL MANIFESTATIONS OF INFECTIVE ENDOCARDITIS. *Brain* 1989;112:1295-1315.
- Hartman L, Barnes E, Bachmann L, Schafer K, Lovato J, Files DC. Opiate Injection-associated Infective Endocarditis in the Southeastern United States. *The American journal of the medical sciences* 2016;352:603-608.
- Bor DH, Woolhandler S, Nardin R, Bruschi J, Himmelstein DU. Infective Endocarditis in the U.S., 1998–2009: A Nationwide Study. *PLoS ONE* 2013;8:e60033.
- Park W, Ahn JS, Park JC, Kwun BD, Lee DH. Treatment Strategy Based on Experience of Treating Intracranial Infectious Aneurysms. *World Neurosurgery* 2017;97:351-359.
- Zanaty M, Chalouhi N, Starke RM, Tjoumakaris S, Gonzalez LF, Hasan D, et al. Endovascular Treatment of Cerebral Mycotic Aneurysm: A Review of the Literature and Single Center Experience. *BioMed Research International* 2013;2013:1-8.
- Ducruet AF, Hickman ZL, Zacharia BE, Narula R, Grobelny BT, Gorski J, et al. Intracranial infectious aneurysms: a comprehensive review. *Neurosurgical Review* 2009;33:37-46.
- Asai T. Endovascular treatment for intracranial mycotic aneurysms prior to cardiac surgery. *European Journal of Cardio-Thoracic Surgery* 2002;21:948-950.
- Singla A, Fargen K, Blackburn S, Neal D, Martin TD, Hess PJ, et al. National treatment practices in the management of infectious intracranial aneurysms and infective endocarditis. *Journal of NeuroInterventional Surgery* 2015;8:741-746.
- Brust JCM, Dickinson PCT, Hughes JEO, Holtzman RNN. The diagnosis and treatment of cerebral mycotic aneurysms. *Annals of Neurology* 1990;27:238-246.
- Corr P, WM, Handler LC. Endocarditis-related cerebral aneurysms: radiologic changes with treatment. *AJNR American Journal* 1995.
- Venkatesh SK, Phadke RV, Kalode RR, Kumar S, Jain VK. Intracranial Infective Aneurysms Presenting with Haemorrhage: An Analysis of Angiographic Findings, Management and Outcome. *Clinical Radiology* 2000;55:946-953.
- Peters PJ, Harrison T, Lennox JL. A dangerous dilemma: management of infectious intracranial aneurysms complicating endocarditis. *The Lancet Infectious Diseases* 2006;6:742-748.
- Tamdy A, El Louali F, Ounzar M, Fettouhi H, Hajkacem H, Fellat I, et al. Multiple mycotic aneurysms reveal *Staphylococcus lugdunensis* endocarditis in a young patient. *Heart & Lung: The Journal of Acute and Critical Care* 2011;40:352-357.
- Allen LM, Fowler AM, Walker C, Derdeyn CP, Nguyen BV, Hasso AN, et al. Retrospective Review of Cerebral Mycotic Aneurysms in 26 Patients: Focus on Treatment in Strongly Immunocompromised Patients with a Brief Literature Review. *American Journal of Neuroradiology* 2012;34:823-827.
- Phuong LK, Link M, Wijdicks E. Management of Intracranial Infectious Aneurysms: A Series of 16 Cases. *Neurosurgery* 2002;51:1145-1152.
- Aspoas AR, De Viluers JC. Bacterial intracranial aneurysms. *British Journal of Neurosurgery* 1993;7:367-376.
- Chun JY, Smith W, Halbach VV, Higashida RT, Wilson CB, Lawton MT. Current Multimodality Management of Infectious Intracranial Aneurysms. *Neurosurgery* 2001;48:1203-1214.
- Kannoth S, Iyer R, Thomas SV, Furtado SV, Rajesh BJ, Kesavadas C, et al. Intracranial infectious aneurysm: Presentation, management and outcome. *Journal of the Neurological Sciences* 2007;256:3-9.
- Yamakawa H, Hattori T, Tanigawara T, Enomoto Y, Ohkuma A. Ruptured Infectious Aneurysm of the Distal Middle Cerebral Artery Manifesting as Intracerebral Hemorrhage and Acute Subdural Hematoma-Case Report. *Neurologia medico-chirurgica* 2003;43:541-545.
- Piastra M, Chiaretti A, Tortorolo L. Ruptured intracranial mycotic aneurysm presenting as cerebral haemorrhage in an infant: case report and review of the literature. *Child's Nervous System* 2000;16:190-193.
- Ong A, Blyth CC, Bency R, Vicaretti M, Harun A, Meyer W, et al. Fatal Mycotic Aneurysms Due to *Scedosporium* and *Pseudallescheria* Infection. *Journal of Clinical Microbiology* 2011;49:2067-2071.
- Koffie RM, Stapleton CJ, Torok CM, Yoo AJ, Leslie-Mazwi TM, Codd PJ. Rapid growth of an infectious intracranial aneurysm with catastrophic intracranial hemorrhage. *Journal of Clinical Neuroscience* 2015;22:603-605.
- Carvalho FGd, Godoy BL, Reis M, Gasparetto EL, Wajnberg E, Souza JMd. Frameless stereotactic navigation for intraoperative localization of infectious intracranial aneurysm. *Arquivos de Neuro-Psiquiatria* 2009;67:911-913.
- Nonaka S, Oishi H, Tsutsumi S, Teranishi K, Tanoue S, Yasumoto Y, et al. Endovascular Therapy for Infectious Intracranial Aneurysm: A Report of Four Cases. *Journal of Stroke and Cerebrovascular Diseases* 2016;25:e33-ee7.
- Sugg RM, Weir R, Vollmer DG, Cacayorin ED. Cerebral Mycotic Aneurysms Treated with a Neuroform Stent: Technical Case Report. *Neurosurgery* 2006;58:E381.
- Sun L-Q. Sensitivity of Computed Tomography Angiography vs Catheter Angiography in the Detection of a Ruptured Intracranial Infectious Aneurysm in a Pregnant Woman. *Archives of Neurology* 2012;69:270.
- Chapot R, Houdart E, Saint-Maurice J-P, Aymard A, Mounayer C, Lot G, et al. Endovascular Treatment of Cerebral Mycotic Aneurysms. *Radiology* 2002;222:389-396.
- Yuen T, Laidlaw JD, Mitchell P. Mycotic intracavernous carotid aneurysm. *Journal of Clinical Neuroscience* 2004;11:771-776.
- Dhomne S, Rao C, Shrivastava M, Sidhartha W, Limaye U. Endovascular management of ruptured cerebral mycotic aneurysms. *British Journal of Neurosurgery* 2008;22:46-52.
- Cheng-Ching E, John S, Bain M, Toth G, Masaryk T, Hui F, et al. Endovascular Embolization of Intracranial Infectious Aneurysms in Patients Undergoing Open Heart Surgery Using n-Butyl Cyanoacrylate. *Interventional Neurology* 2017;6:82-89.