A Prospective Observational Study Of The Use Of Intraoperative Dye Based Video angiography In Microsurgical Management Of Intracranial Vascular Pathologies

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ABSTRACT

Aim: To evaluate the use of intraoperative dye based video angiography in microsurgical management of intracranial vascular pathologies.

Material and Methods: The present non randomized prospective observational study was conducted in the Department of Neurosurgery, Bangur Institute of Neurosciences & SSKM Hospital, IPGME &R, Kolkata during Dec 2020 – Dec 2023 among patients admitted to our institute with radiological evidence of intracranial vascular pathologies (Aneurysms, AVMs). **Results**: Incidence of Aneurysm and AVM among the study subjects was 64% and 36% respectively. Most common symptom among the study subjects was headache (92%) followed by altered sensorium (48%). Most common complication among the study subject during follow up was cerebral vasospasm (14%) and aneurysm rupture (8%). Indocyanine green video angiography (ICG VA) was found to be useful in 98% of the surgical procedure however it influence surgery in 44% of the cases.

Conclusion: ICGFV is an intuitive method that provides neurosurgeons with high-quality, reliable, real-time information regarding cerebrovascular anatomy, which can assist in improving intra-operative surgical management and stroke prevention.

Keywords: Intracranial Vascular Pathologies, Intraoperative, Dye Based Videoangiography

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INTRODUCTION

Complex cerebral aneurysms contain not only giant aneurysms (greater than 25 mm in diameter) but also some aneurysms characterized by large (15–25 mm), difficult locations, previous treatment, presence or absence of collateral circulation, intraluminal thrombus, and calcification of the aneurysmal wall[1].

The treatment method should be decided carefully with the consideration of advanced endovascular technology such as modified stents and novel embolic agents perhaps improving therapeutic effect for these complex aneurysms[2]. Once the surgical procedure is adopted, direct clipping becomes the most common strategy[3]. When the direct approach is impractical or at-risk, alternative approaches including trapping with or without flow replacement (bypass), primary proximal vessel occlusion (Hunterian ligation), and distal vessel occlusion can be used[4]. Intraoperative Doppler ultrasound and flowmetry are effective for detection of major vessel stenosis after aneurysm clip placement. However, these techniques do not have high accuracy and only provide an indirect assessment of vessel lumen compromise[5-7].

Fluorescence angiography with fluorescein sodium and indocyanine green (ICG) was introduced for neurovascular procedures in the 1960s. Initially, fluorescence angiography was used for observation of vessels on the brain surface; static images were captured and analyzed after surgery[8]. This evolved into modern videoangiography: fluorescence excitation sources and filters integrated into the operative microscope allow acquisition of multiple video loops that can be analyzed intraoperatively[9]. Observation of a fluorescent contrast agent introduced into the vasculature allows assessment of local blood flow dynamics. Multiple clinical trials have shown the effectiveness of fluorescence angiography in the management of vascular pathologies of the brain and spinal cord[10].

Currently, ICG videoangiography is acquired as video loops on an integrated camera after switching the white light optics to a NIR filter set. Light from the field is directed to the camera, and, with the exception of some small background bleed through, the NIR image contains only fluorescence emitted from the ICG while the white light image is recorded independently[11].

Indocyanine green video angiography (ICG-VA) has been widely used in vascular neurosurgery, especially in cases of aneurysms, arteriovenous malformations (AVMs), and bypass, to assess the cerebral blood flow since its introduction in 2003[12-13]. The potential disadvantages of conventional ICG-VA include that it only evaluates the blood flow within the field of view and lacks quantitative analysis of the angiography images[14].

Due to scarcity of data, the present study was conducted to evaluate the use of intraoperative dye based videoangiography in microsurgical management of intracranial vascular pathologies with the following objectives:

1. To evaluate the efficacy of intra operative Indocyanine green video angiography (ICG VA) in Aneurysm, brain arteriovenous malformations (AVM) and extracranial intracranial (EC-IC) bypass surgeries and also to analyze its limitations.
2. To co-relate the real time information available intraoperatively with that of the postoperative radiological images.

METHODOLOGY

The present non Randomized prospective observational study was conducted in the Department of Neurosurgery, Bangur Institute of Neurosciences & SSKM Hospital, IPGME &R, Kolkata from Dec 2020 – Dec 2023 among 50 patients admitted to our institute during the study period with radiological evidence of intracranial vascular pathologies (Aneurysms, AVMs)

INCLUSION CRITERIA

Patients admitted with history of spontaneous SAH due to Aneurysmal rupture/AVM bleed, all of whom underwent microsurgical management.

EXCLUSION CRITERIA

- Individuals/Legal guardian not willing to participate in the study.
- Intra operative death.
- Lost to follow up.
- The patients undergoing Endovascular treatment

PROCEDURE

All vascular procedures including AVMs are performed using ICG-VA and analysis by this software. After surgically exposing the AVM, a primary ICG-VA is performed after intravenous injection of ICG (25 mg dissolved in 10 cc sterile water) to obtain primary anatomical and physiological information of the vessels. Color-coded image from FLOW 800 is used to differentiate cortical feeding artery and vein at a glance which guides the surgeon to adopt the appropriate strategy toward the lesion. Any region of interest (ROI) can be defined for the software to provide semi-quantitative information of its hemodynamic properties. Some parameters are calculated directly by the software including average intensity (showed in arbitrary intensity units), delay time (i.e., the time interval from 0% to 50% of maximum fluorescence intensity [MFI]), and the slope of the curve. On the other hand, there are some other indices presented in the literature known to be correlated with perfusion characteristics of tissues which simply can be computed with Image J software (version 1.46, National Institute of Health, USA) after delivering the data from the microscope station. Transit time is the time interval between MFI in the artery and parenchyma, and rise time is defined as the time during which fluorescence intensity rises from 10% to 90% of its peak. Other variables that can be measured manually include MFI, time to peak (i.e., from the appearance of fluorescence to MFI), and cerebral blood flow index (CBFI) which is defined as the ratio of MFI to rise time. These parameters can be calculated for each vessel, and their changes should be tracked throughout the procedure. We still doubt the validity and reliability of these semi-quantitative data for clinical judgment, and their application is under further investigations in our institute. While maintaining the gliotic plane around the AVM and exposing the deeper aspects of the lesion, further images would be obtained at the request of the surgeon. New semi-quantitative data regarding the surrounding brain parenchyma should be constantly compared with the previous information. As the resection progresses, color changes in blood vessels may help the surgeon to take the next step. For example, abnormal blood flow in a draining vein at the end of the procedure usually indicates a hidden arterial feeder and necessitates a search for it[15].

DATA COLLECTION

1. Traumatic Subarachnoid hemorrhage and vascular lesions being managed endovascularly were excluded from this study.
2. Various complications of surgical management of aneurysms and AVMs were noted during the hospital course and up to the 1 year of follow up.
3. Various complications like Vasospasm, residual nidus, post op seizures, CSF leak, pseudomeningocele, wound infection, wound dehiscence, hydrocephalus, bone flap infection/osteomyelitis if replaced.
4. Various complications of surgical management of aneurysms/AVMs were studied under following headings:

a. Incidence.
b. Duration of onset of complications.
c. Complication directly causing mortality.
d. Management of complications.
e. Steps that can be taken to prevent the occurrence.
f. The Glasgow outcome score was used and was recorded at the time of discharge, three months, six months and 1 year post intervention.

FOLLOW UP

1. Various complications of aneurysmal clipping/AVM resection of during the hospital course and up to 1 year of follow up were recorded.
2. The median Glasgow outcome score for all the subjects was determined day after surgery, on discharge, at 3 months and at 6 months. Outcomes were divided into two groups i.e. good (Score of 3 or 4) and poor (score 1 or 2 and death).

Data was collected and subjected to statistical analysis.

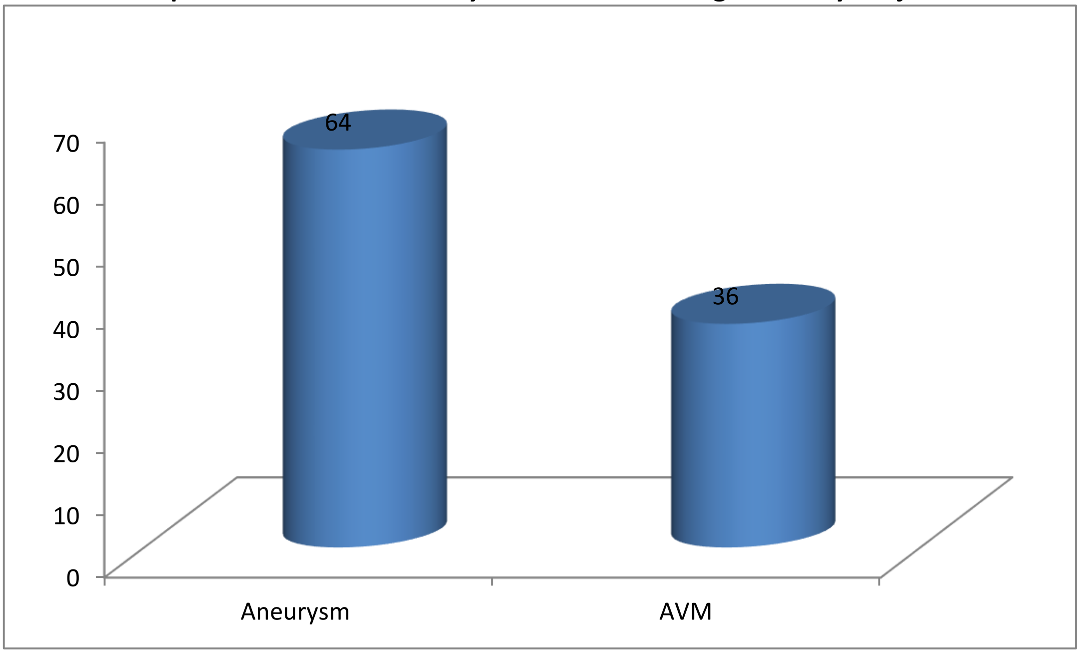
STATISTICAL ANALYSIS

Data so collected was tabulated in an excel sheet, under the guidance of statistician. The means and standard deviations of the measurements per group were used for statistical analysis (SPSS 22.00 for windows; SPSS inc, Chicago, USA). Difference between two groups was determined using t test as well as chi square test and the level of significance was set at $p < 0.05$.

RESULTS

Out of 50 subjects, there were 43 (86%) females and 7 (14%) males. Hence there was female dominancy in this study. The mean age among the study subjects was 51.98±12.77 years. Incidence of Aneurysm and AVM among the study subjects was 64% and 36% respectively (graph 1).

Graph 1: Incidence of Aneurysm and AVM among the study subjects



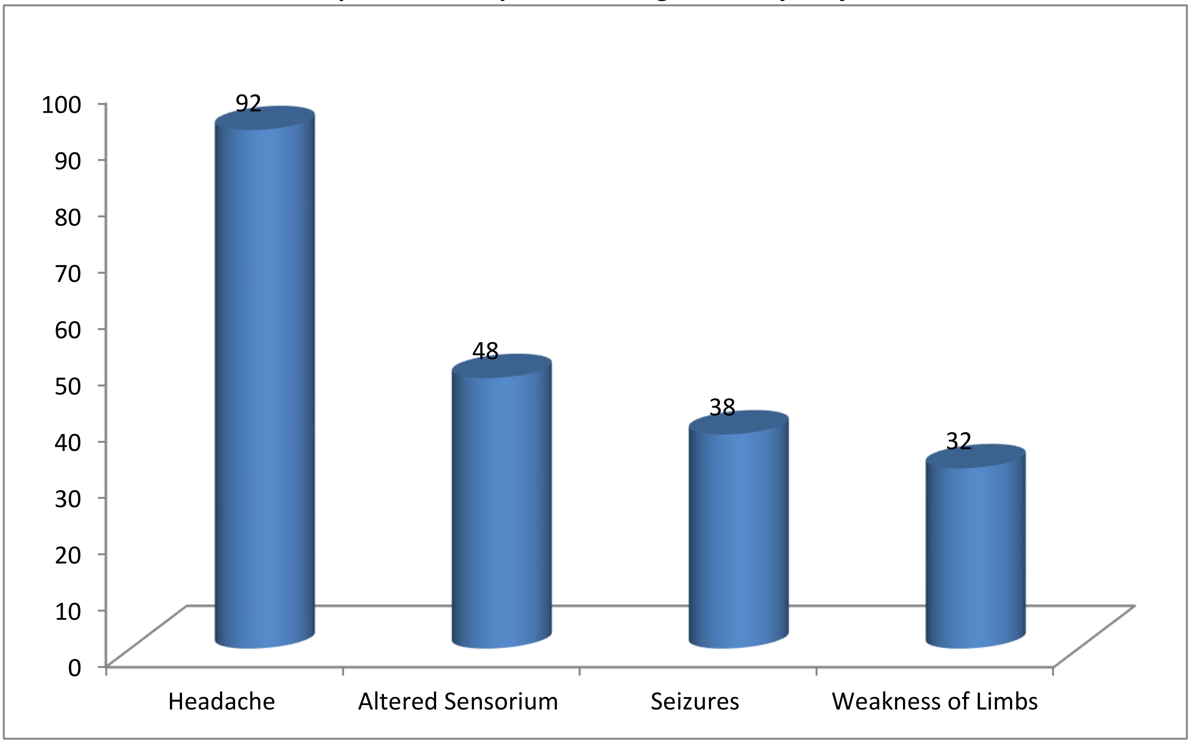
In this study, mean aneurysm size was found to be 51.98±12.77 mm. SAH was found among 54% of the study subjects. 14% of the subjects had GCS score between 7-9 while 58% had score between 13-15. mRS grade 1, 2, 3, 4 and 5 was revealed in 38%, 26%, 12%, 10% and 14% of the subjects respectively (table 1).

Table 1: SAH, GCS and mRS grade distribution among the study subjects

Variables	**N**	**%**
SAH	27	54
GCS		
0-3	0	0
4-6	0	0
7-9	7	14
10-12	14	28
13-15	29	58
mRS Grade		
0	0	0
1	19	38
2	13	26
3	6	12
4	5	10
5	7	14

Graph 2 shows the clinical profile among the study subjects. Most common symptom among the study subjects was headache (92%) followed by altered sensorium (48%). Seizures and weakness of limbs was revealed in 38% and 32% of the subjects respectively.

Graph 2: Clinical profile among the study subjects



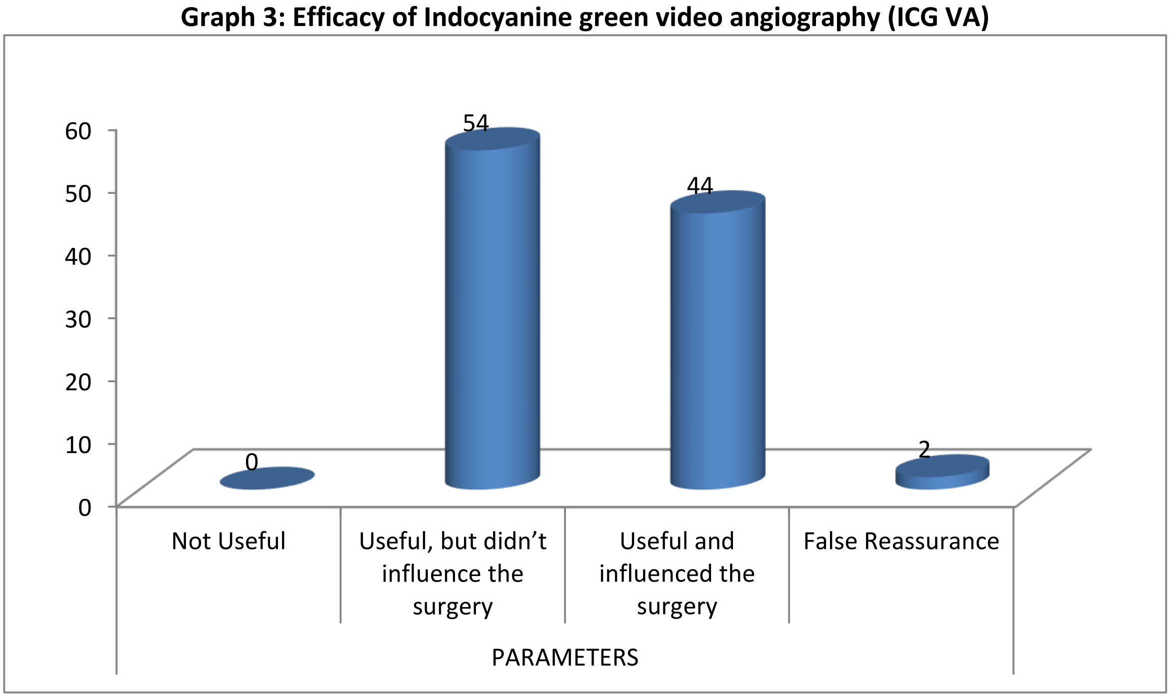
Most common complication among the study subject during follow up was cerebral vasospasm (14%) and aneurysm rupture (8%). Cerebral edema and infarction was found in 4% of the subjects each while intracranial and pulmonary infection was reported in 2% of the subjects each. Mortality was reported among 26% of the subjects. Mortality was found to be significantly associated with complications (table 3).

Table 3: Association of mortality and complications

Complications	Outcome	
	Survivor	Non Survivor
Cerebral Vasospasm	3	4
Aneurysm Rupture	1	3
Cerebral Edema	0	2
Cerebral Infarction	0	2
Intracranial Infection	0	1
Pulmonary Infection	0	1
p value	0.009*	

*: statistically significant

Graph 3 shows the efficacy of Indocyanine green video angiography (ICG VA) during surgery. Indocyanine green video angiography (ICG VA) was found to be useful in 98% of the surgical procedure however it influence surgery in 44% of the cases.



DISCUSSION

Indocyanine green fluorescence videoangiography (ICGFV) is an emerging intra-operative neurovascular imaging modality. This technique was first approved for cardiac circulatory assessment, liver function diagnostic use and ophthalmic angiography. In recent years, it has been adopted into neurosurgery with large centres in Germany, USA and Japan reporting positive experience with this technology. However, its use in Indian neurosurgical centres has not been widely documented. The use of intra-operative ICGFV has been reported to provide surgeons with timely and important information leading to changes in intraoperative surgical management. In one series, aneurysm clip repositioning based on ICGFV findings occurred in 9% of cases[16].

Out of 50 subjects, there were 43 (86%) females and 7 (14%) males. Hence there was female dominancy in this study. The mean age among the study subjects was 51.98±12.77 years. Tao Xue et al[17] in their study too found that patients ranged in age from 17 to 77 years (mean age of 54 years) with a gender ratio of 1:5.4 (male/female). In a study by Vini G. Khurana et al[18], similar female dominancy and age was found i.e. there were 30 females and 14 males. The average age was 48.6 years (range 17–77 years).

SAH was found among 54% of the study subjects. 14% of the subjects had GCS score between 7-9 while 58% had score between 13-15. mRS grade 1, 2, 3, 4 and 5 was revealed in 38%, 26%, 12%, 10% and 14% of the subjects respectively. In this study, mean aneurysm size was found to be 51.98±12.77 mm. Anterior and posterior circulation was reported among 86% and 14% of the subjects respectively. Similar characteristics were reported by K. Kaiser et al[14], Gruber Andreas et al[19], Tao Xue et al[17] and Vini G. Khurana et al[18] in their studies.

Most common complication among the study subject during follow up was cerebral vasospasm (14%) and aneurysm rupture (8%). Cerebral edema and infarction was found in 4% of the subjects each while intracranial and pulmonary infection was reported in 2% of the subjects each. Huang et al[20] in their study revealed similar complications among the study subjects.

In the present study, mortality was reported among 26% of the subjects. There were 87 cases with a good prognosis and 15 cases with a poor prognosis as mentioned by Huang et al[20] in their study. This is approximately similar to the present study.

Indocyanine green video angiography (ICG VA) was found to be useful in 98% of the surgical procedure however it influence surgery in 44% of the cases. The exceptional patient (had presented with a large intraparenchymal haemorrhage with intraventricular extension secondary to a Spetzler-Martin grade 3 left insular AVM with associated intraventricular venous aneurysm. A craniotomy was performed to shut down the AVM. With the use of ICGFV, the arterial feeding vessels were thought to be shut down as no residual fluorescence was observed in the nidus. Unfortunately, post-operative DSA showed a residual feeding artery and the remaining partial nidus adjacent to the original excision. A second operation was performed to complete the shutdown of the AVM.

Vini G. Khurana et al[18] in their study showed that the use of intra-operative ICGFV benefited a total of 34 of 46 cases (74%). ICGFV was found to be particularly useful in emergency surgeries involving ruptured or complex aneurysms where the aneurysm anatomy and relevant pre- and post- vascular anatomy was difficult to visualise directly. Surgery for most of the simple saccular unruptured aneurysms undergoing elective clipping did not substantially benefit from ICGFV, as the pertinent vascular anatomy was evident by direct visualisation. In 12 of the 46 cases (26%), ICGFV led to crucial intra-operative surgical changes. These findings are similar to the present study.

The authors found that ICGFV is quick, easy and intuitive, consistent with the experience of others. Its real-time high-resolution images are adequate to visualise and preserve the small but important perforating arteries. Besides aneurysm clipping, various cerebrovascular cases such as EC-IC bypass, DAVF disconnection and AVM excision could benefit from the use of intra-operative ICGFV[18]. Raabe et al[10] demonstrated that although intraoperative DSA provides the most accurate and therefore the gold standard for intra-operative cerebrovascular imaging, intra-operative ICGFV is both useful as an independent form of angiography or as an adjunct to intra- or post-operative DSA. Its routine use in aneurysm clipping is highly recommended, especially in centres where intra-operative angiography is not available.

Similarly Gruber Andreas et al[19] in their study revealed that the information from DSA and ICGA corresponded in 120 of 123 aneurysms operated on (97.5 %). In 1 patient, ICGA underestimated a relevant parent artery stenosis detected by digital subtraction angiography. In 2 patients with relevant aneurysmal misclipping, digital subtraction angiography and ICGA led to conflicting results that could be clarified only when both methods were used and interpreted together.

LIMITATIONS OF ICG

The authors recognise that ICGFV is qualitative rather than quantitative. It is conceivable that despite observing what appears to be good distal vessel fluorescence in the relevant vessels, ICGFV might not demonstrate diminished volume flow in these vessels. Despite the limitation that ICGFV is non-quantitative in terms of blood flow measurement, we found that it still reliably predicted post-operative clinical and radiological outcome. Compared to DSA, the area and depth of ICGFV visualization is limited, especially in circumstances such as excision of a large AVM.[86] This limitation is due to the amount of surgical exposure or any physical obscuration of the 'line-of-sight' between the fluorescing vasculature and the microscopemounted NIR camera. Within these important limitations, Takagi et al demonstrated that the use of ICGFV is a safe and easy method for assessing the completeness of AVM excision. In our limited experience, ICGFV should be used in more technically difficult AVM and DAVF cases in conjunction with intra-operative or post-operative DSA in the future[21].

Unfortunately, intra-operative cerebral angiography is not readily available in many centres, including our own. Intra-operative angiography requires additional equipment set-up, a radiographer, an interventional radiologist, more theatre space, and other logistic support.[7] It is an invasive procedure associated with unlikely but important complications such as focal neurological deficit secondary to embolic CVA and lower limb ischaemia secondary to femoral artery thrombosis (0.4–2.6%). To improve cost-effectiveness and benefit-risk ratio, it has been suggested that intra-operative DSA be used selectively.

CONCLUSION

ICGFV is an intuitive method that provides neurosurgeons with high-quality, reliable, real-time information regarding cerebrovascular anatomy, which can assist in improving intra-operative surgical management and stroke prevention. It has technical limitations that need to be understood. We cannot overemphasise the potential for enhancement of patient safety in those undergoing high-risk neurosurgical procedures using this emerging technology. We believe that this work demonstrates the utility of this technology in a wide array of intracranial procedures such as aneurysm and AVM.

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