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RESEARCH

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Volume embolization ratio of coiled cerebral aneurysms, does awake technique affect the results?

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Abstract

Background Despite the great innovations in the neuroendovascular techniques and related materials, there are still notable percentages of recurrent cerebral aneurysms after aneurysm coiling. Aneurysm packing density is well known to affect the initial angiographic result of aneurysm embolization and has a crucial role in the stability of aneurysm obliteration. Although aneurysm coiling is commonly performed under general anesthesia, it could be performed under local anesthesia in certain circumstances.

Objective The purpose of this study is to compare the volume embolization ratio (VER) and angiographic results of cerebral aneurysm embolization performed under local and general anesthesia.

Materials and methods This is a retrospective cohort analysis of 20 consecutive cases of coiled cerebral aneurysms that were coiled under LA. Further, 15 cerebral aneurysm coil embolization cases have been collected from our data as matched control group.

Results Embolization was performed under local anesthesia (Group A) in 20 patients (57.1%) and under general anesthesia (Group B) in 15 patients (42.9%). At the end of the procedure, control angiogram revealed complete obliteration in 13 patients (37.1%), while incomplete obliteration was detected in 22 patients (62.9%). The mean VER 27.9 ± 11.8 without a significant difference between both groups of the study as the VER of Group (A) was 26.05 ± 8.4 and that of Group B was 30.44 ± 15.2. Follow-up angiography at 1 year revealed complete obliteration in 17 (48.6%) of the coiled aneurysms, while incomplete obliteration was detected in 18 patients (51.4%).

Conclusions Endovascular coiling of cerebral aneurysms under local anesthesia is a safe and feasible procedure without significant effects on the VER.

Keywords Local anesthesia, Awake technique, Cerebral aneurysm, Coiling, Volume embolization ratio

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Background

Cerebral aneurysms are fairly common intracranial pathology with a prevalence ranging from 1 to 5% among general adults populations [1, 2], while the incidence of aneurysmal subarachnoid hemorrhage is 10–16 per 100,000 people per year [3, 4].

Management of cerebral aneurysms has been developed over decades from ligation of the proximal artery to clipping of the aneurysm neck until the current era of endovascular treatment [5, 6].

Over the past three decades, great and continuous advancements in the technology of coil materials have been achieved starting from the first Guglielmi detachable coil (GDC) in 1991 till the era of bioactive coils, aiming at complete aneurysm obliteration; however, the ultimate degree of aneurysm obliteration is still widely variable [7, 8].

The endovascular intervention has an increasing role in the armamentarium of cerebral aneurysm management and has succeeded in preventing early re-bleedings; nevertheless, there is a 2.2% incidence of subsequent hemorrhagic rate among patients with ruptured aneurysms with incomplete angiographic obliteration [9].

Multiple factors could affect aneurysm recurrence after endovascular coiling including rupture status [10], degree of completeness of aneurysm occlusion at the time of initial treatment [9], while the location of aneurysms is still a controversial factor [12, 13].

Aneurysm packing density affects the initial angiographic result of aneurysm embolization and has a crucial role in the stability of aneurysm obliteration [14, 15]. Aneurysm packing density could be objectively measured using the volume embolization ratio (VER) which is defined as the embolized volume of the aneurysm lumen and could be calculated mathematically by the ratio of coil volume to aneurysm volume [14, 15] using different methods [16].

Though aneurysm coiling is usually performed under general anesthesia, it could be also performed under local anesthesia (LA) with or without sedation which can be considered as an alternative tactic for coiling. Neuroendovascular intervention while the patient is awake, permits continuous neurological monitoring, eliminates the risks of general anesthesia, and can shorten the length of the procedure [17].

To the best of our knowledge, no previous research has studied the potential difference in VER and subsequent angiographic results among embolized cerebral aneurysms performed under local anesthesia to matched cohort of patients' aneurysms when the embolization procedures were performed under GA.

Objective

The purpose of this study is to compare the VER and angiographic results of cerebral aneurysm embolization performed under local and general anesthesia.

Materials and methods

This is a retrospective cohort analysis of 20 consecutive cases of coiled cerebral aneurysms that were coiled under LA. Further 15 cerebral aneurysms coil embolization cases, performed under GA, have been selected from our data as matched control group.

The matched cohort was selected based on (age, gender, comorbidities, aneurysm size, aneurysm dimensions, as well as aneurysm locations.

All patients in the LA group were given only lidocaine 1% topical infiltration at the femoral puncture site. Thorough discussion and explanation of the procedure with the patient before going to the Angio Suite were carried out to clarify facts and to fight unjustifiable fears from the decided endovascular procedure. General anesthesia was used if the patient was noncooperative, restless or according to the choice of the patient. All cases were performed using bare platinum coils.

All cases were treated between the period of 2013 and 2018 with angiographic follow-up at 1 year. Patients with a giant cerebral aneurysm, posterior circulation aneurysms, multiple aneurysms, with follow-up less than 1 year and those with incomplete data were excluded. Regarding Hunt and Hess grading of the patients included in this study; for LA patient group all were H&H = 0, while GA patient group all were H&H grade 3 or less.

The primary outcome is the volume embolization ratio at the final control angiogram while the secondary outcome is the stability of the aneurysm after initial coiling at 1-year angiographic follow-up. The primary exposure variable in this study is the type of anesthesia whether general or local anesthesia, while secondary exposure variables included demographic data (age, gender) and aneurysm criteria (volume, site and size of the aneurysm).

In this study, the calculation of VER was performed through the usage of software called Angio Suite [18]. Two-dimensional angiographic images of the aneurysm were captured and used to calculate the aneurysm volume, and then menus listing all commercially available coils were used to estimate the packing density.

In this study, Montreal scale (Raymond-Roy) was used for the evaluation of the degree of aneurysm obliteration after coil embolization which includes class I when there is complete aneurysm obliteration (CO) with no intrasaccular contrast opacification, class II (residual neck) which was defined as the presence of any portion of the original defect of the arterial wall in any single projection without opacification of the aneurysmal sac while in cases with opacification of the aneurysmal sac, it was considered class III (residual aneurysm) [19].

In the current study, stability of the aneurysm coiling was considered whenever there is complete aneurysm obliteration at 1-year angiographic follow-up, or when there is a stable neck remnant in comparison with the initial control angiogram.

Our policy in treating unruptured aneurysms goes greatly with the International Study of Unruptured Intracranial Aneurysms (ISUIA) [20], with some more considerations including; patient wish to be definitely treated instead of watchful expectancy, irregular outer aneurysm wall with daughter sacs, increasing size of the aneurysm on follow-up, history of previous SAH, family history of SAH, etc. So, after thorough discussion with unruptured aneurysm patient ± his close family, a decision was tailored on an individual basis.

Regarding used coils and catheters, we always use available on shelf catheters and coils without any commercial constraints and the decision was usually made based on the case own specifications.

Statistical analysis

A statistical analysis was carried out using Stata Software version15, descriptive statistical data were summarized as mean ± SD, median and/or proportions as appropriate. The correlation between the exposure factors and outcome was completed using a correlation coefficient. We compared the mean, median or proportion of the exposure factors between patients who were treated under local anesthesia and who were treated under general anesthesia using *t* test, logistic regression test, chi-square test, Fisher's exact test and Kruskal–Wallis equality-of-populations rank test as appropriate according to the type of the variable. Statistical significance was considered with P value < 0.05.

Results

Out of the thirty-five patients in this study, 21 patients (60%) were female and 15 (40%) were male, and their ages ranged from 39 to 81 years with a mean age of 59.7 ± 10.6 years without any statistically significant difference between the two groups of the study (Table 1).

In the current study, only five patients (14.3%) were treated for ruptured cerebral aneurysms while the remaining thirty patients (85.7%) were treated for unruptured cerebral aneurysms.

The majority of the included patients in the current study were treated for unruptured cerebral aneurysms (30 patients, 85.7%), while only 5 patients (14.3%) were treated for ruptured aneurysms. All patients included in this study harbor anterior circulation aneurysms, where twenty-three aneurysms (65.7%) were located at the internal carotid artery (ICA), four aneurysms (11.4%) were located at the Middle cerebral artery (MCA), while eight aneurysms (22.9%) were located at the anterior communicating artery (AcomA) (Table 1). No statistically significant difference was found between the two studied patient groups regarding the aneurysm location or the initial clinical presentation (Table 1).

In this study, the size of the smallest aneurysm was 3 mm and that of the largest was 15.5 mm with a mean aneurysm size of 5.6 ± 2.6 mm, while the lowest aneurysm volume was 11.1 mm^3 and the largest aneurysm volume was 259.8 mm^3 with an average volume of 57.9 ± 56.2 mm^3 without any statistically significant difference between the two study groups.

The procedures were carried out under local anesthesia (Group A) in 20 patients (57.1%), while in Group B, the procedures were performed under general anesthesia (15 patients, 42.9%).

At the end of the procedures, control angiogram revealed complete obliteration (CO) among 12 patients (34.3%), while incomplete obliteration was observed among 23 patients (65.7%). Out of the 23 patients with incomplete obliteration, the presence of neck remnant (NR) was encountered in 19 aneurysms (54.4%) and body filling (BF) was found in 4 patients (11.4%).

Table 1 Patients and aneurysm criteria

	Total (35)	Embolization under LA (20)	Embolization under GA (15)	*P* value
Age	59.7 ± 10.6	60.3 ± 11	58.8 ± 10.3	0.68
Male	14 (40%)	7 (35%)	7 (46.7%)	0.48
Females	21 (60%)	13 (65%)	8 (53.3%)	
Ruptured aneurysm	5 (14.3%)	1 (5%)	4 (26.7%)	0.07
Unruptured aneurysm	30 (85.7%)	19 (95%)	11 (73.3%)	
Aneurysm volume	57.9 ± 56.2	62 ± 54.4	52.4 ± 60	0.62
Aneurysm size	5.6 ± 2.6	5.6 ± 2.7	5.6 ± 2.5	0.9
Aneurysm site				
ICA	23 (65.7%)	13 (56.5%)	10 (43.5%)	0.9
MCA	4 (11.4%)	2 (50%)	2 (50%)	
AcomA	8 (22.9%)	5 (62.5%)	3 (37.5%)	

Table 2 Radiological outcome after aneurysm coiling

	Total (35)	Embolization under LA (20)	Embolization under GA (15)	*P* value
Volume embolization ratio	27.9 ± 11.8	26.05 ± 8.4	30.44 ± 15.2	0.28
Control DSA				
Complete	13 (37.1%)	10 (50%)	3 (20%)	0.07
Incomplete	22 (62.9%)	10 (50%)	12 (80%)	
Follow-up DSA				
Complete	17 (48.6%)	12 (60%)	5 (33.3%)	0.1
Incomplete	18 (51.4%)	8 (40%)	10 (66.7%)	

A relatively higher rate of initial CO was found in Group A (9 patients, 45%), while a lower rate was found in Group B (3 patients, 20%), yet there was no statistically significant difference ($P = 0.07$, Table 2).

The minimum VER in this study was 11.9 and the maximum VER was 73.9 with mean VER 27.9 ± 11.8 without a statistically significant difference between both groups of the study, as the VER of Group A was 26.05 ± 8.4 and that of Group B was 30.44 ± 15.2 (Table 2).

At 1-year follow-up angiogram, complete obliteration was observed among 17 (48.6%) of the coiled aneurysms, while incomplete obliteration was detected among 18 coiled aneurysms (51.4%). Out of the 18 aneurysms with incomplete obliteration at 1-year follow-up, 15 showed neck remnant (42.9%) and body filling was encountered in 3 aneurysms (8.6%) with a higher rate of complete obliteration in Group (A) than Group (B) but without statistically significant difference between the study groups.

Angiographically progressive aneurysm obliteration to CO was observed among 5 aneurysms with initial results of neck residual (NR), and one aneurysm with initial results of BF, while stable CO was encountered among 11 out of 12 aneurysms with initial results of CO.

Stable angiographic NR was encountered in 12 out of 19 aneurysms at 1-year follow-up (FU), progressive aneurysm obliteration from BF to NR was seen in two aneurysms, and on the other hand, two aneurysms with initial results of NR regressed on 1-year follow-up angiogram to BF. Two aneurysms with an initial angiographic result of BF remain the same at 1-year FU (Table 3).

At 1-year FU angiogram, complete obliteration in Group (A) was found in 12 patients (60%), while complete occlusion was detected in 5 patients (33.3%) of the patients in Group (B) (Table 2).

Discussion

Endovascular treatment of cerebral aneurysms has emerged as a promising alternative to surgical clipping. Continuous advancement in the technology of coil materials starting from the first Guglielmi Detachable Coils (GDC) in 1991 to the era of bioactive coil has made endovascular management the first line of treatment in cases of intracranial aneurysms whenever it is available and technically achievable.

Endovascular therapy has markedly reduced the rate of early re-bleeding; however, it might not eliminate the risk of late aneurysmal hemorrhages [21, 22]. Therefore, the need to establish stable aneurysm obliteration after coiling is mandatory to avoid aneurysm recurrence and subsequent risk of re-bleeding.

The rate of recanalization after aneurysm coiling is relatively high [21, 22] and a recurrence rate of 33% was reported in a large single-center study [23]. However, there is widely variable inter-observer agreement on the degree of aneurysm obliteration [24, 25].

Cerebral aneurysm recurrence risk is a multifactorial consequence that could be affected by aneurysm rupture

Table 3 Stability of the aneurysm after coiling

Initial angiographic results	Follow-up angiographic results			
	Complete obliteration	Neck remnant	Body filling	Total
Complete obliteration	11 (91.7%)	1 (8.3%)	0	12 (34.3%)
Neck remnant	5 (26.3%)	12 (63.2%)	2 (10.5%)	19 (54.3%)
Body filling	1 (25%)	2(50%)	1 (25%)	4 (11.4%)
Total	17 (48.6%)	15 (42.8%)	3 (8.6%)	35 (100%)

status [10], degree of completeness of aneurysm obliteration at the time of initial treatment [11], aneurysm size [15, 26], aneurysm location [12, 13], in addition to aneurysm neck coverage [27].

Volume embolization ratio (VER) could be considered as a useful and objective indicator for packing density following an aneurysm embolization [14]. As a corollary, aneurysm packing attenuation of 18–24% has been reported to reduce the rate of aneurysm recurrence [26]. Sluzewski et al. found that aneurysm packing of at least 24% whenever its original volume is less than 600mm^3 prevents coil compaction. Nevertheless, in small-sized cerebral aneurysms with volume less than 200 mm^3, compaction did not occur when VER is more than 20%. However, high VER could not be achieved in large aneurysms (volume > 600 mm^3), with subsequent coil compaction in most cases [15].

On the other hand, the volume of inserted coils can be accurately measured, whereas accurate calculation of aneurysm volume from 2D angiographic images is more complex, but with the use of 3D imaging and volume measurement software applications (Neurovision 1-Tokyo-Japan and others), aneurysm volume can also be accurately measured [16].

Cerebral aneurysm coiling is commonly performed under general anesthesia as the need for high-quality and motionless images is needed to minimize motion artifact that facilitates accurate intervention. In addition, it allows better control of arterial blood pressure, ventilation, and ICP but general anesthesia in the radiology suite is a challenge for anesthesiologist, especially in the presence of dim lighting plus the lack of a full range of anesthetic equipment that is available in the main operating theaters [28]. The disadvantages of GA also include the inability to perform intraoperative neurological assessment and the consequences of endotracheal intubation which may produce systemic hypertension, coughing or straining which can lead to raised ICP with increased risk or re-bleeding [29]. Local anesthesia (LA) with or without sedation can be an alternative for GA during cerebral aneurysm coiling procedures, in addition to the general potential advantages of local anesthesia over GA which include lower cardiopulmonary morbidity, shorter hospital stay and lower hospital costs [17]. LA also allows intraprocedural evaluation and has the advantage of conducting intermittent neurological examination during the procedure and facilitates neurological evaluation [30]. The feasibility and safety of LA for endovascular treatment of unruptured intracranial aneurysms have been studied before [31] with a 99% success rate [32].

In the current study, the impact of local anesthesia on the aneurysm packing density was studied through evaluation of the VER and compared with matched control group who were operated under GA.

In this study, the minimum VER was 11.9 and the maximum VER was 73.9 with a mean VER of 27.9 ± 11.8.

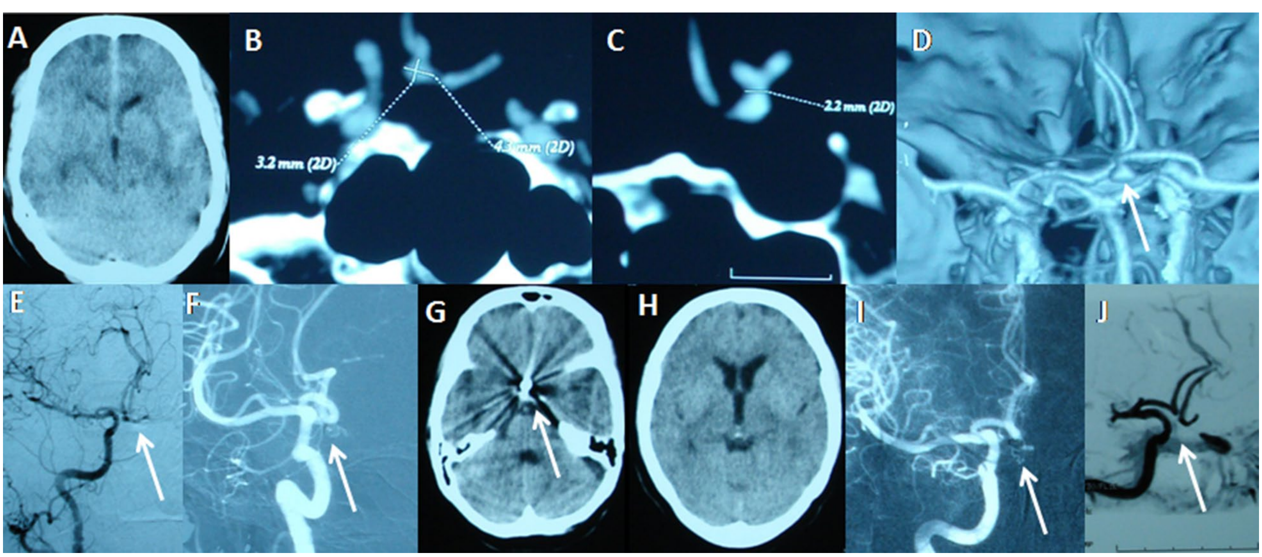

Fig. 1 LA case 41-year-old lady presented to our hospital by SAH from ruptured AcomA aneurysm H&H = 1. **A** Non-enhanced axial CT brain showed diffuse SAH with main cast at the anterior interhemispheric fissure, **B**, **C** preoperative CT angiogram with 2D showed small narrow neck AcomA aneurysm directed anteroinferiorly with the following dimensions (3.2 × 4.3 × 2.2 mm), **D** preoperative CT angiogram volume rendering 3D reformate demonstrating the shape and direction of the AcomA aneurysm, **E**, **F** preoperative and completion (End of procedure) DSA A–P view showing the AcomA aneurysm before and after complete obliteration (CO) under LA, **G**, **H** post-coiling axial CT brain showed the metallic coil artifact with no post-procedural sequelae, **I**, **J** 1-year postprocedural FU DSA, MRA that showed stable complete obliteration of the aneurysm (CO).

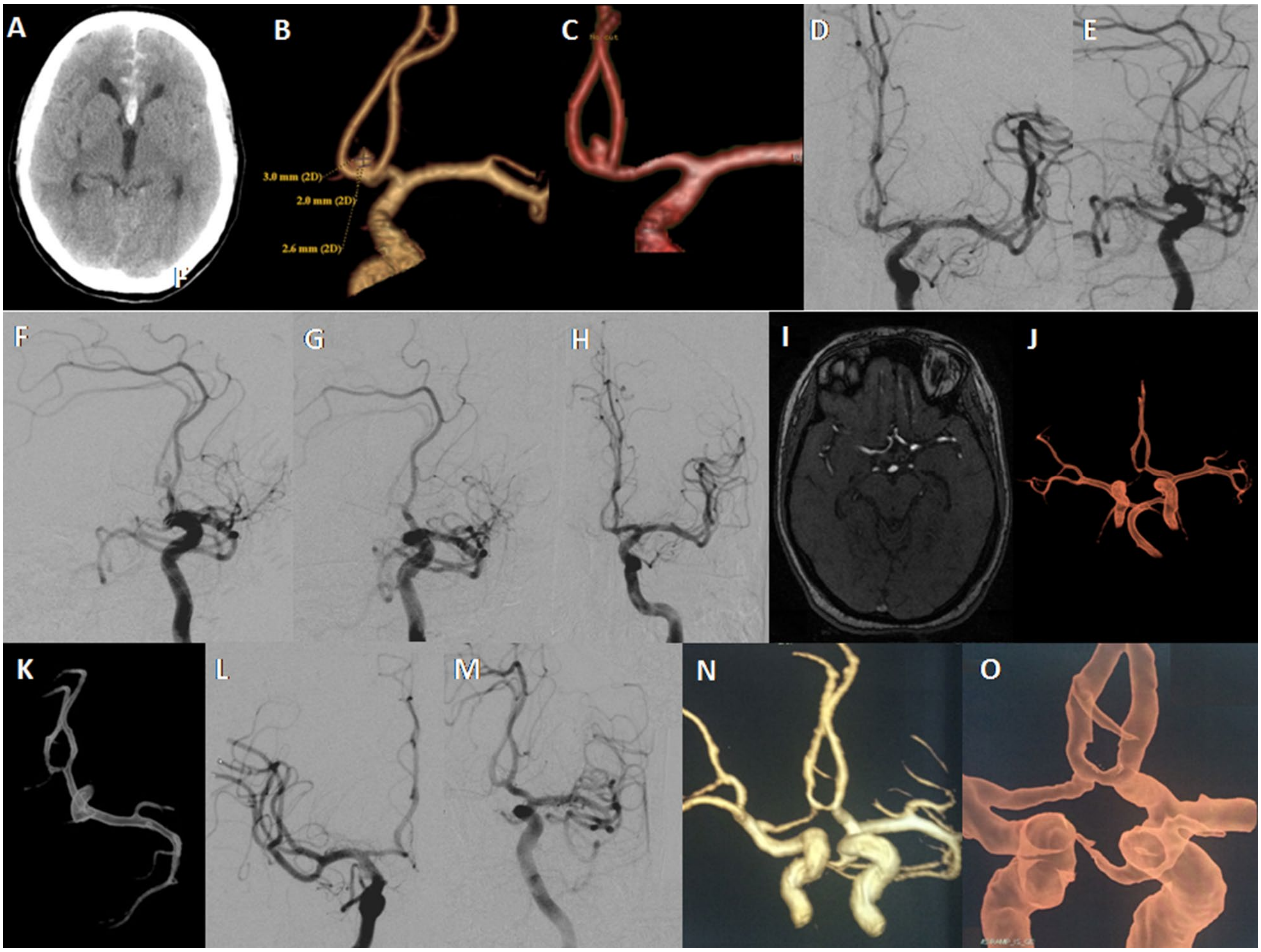

Fig. 2 GA case 52-year-old lady presented to our hospital by SAH from ruptured AcomA aneurysm H&H = 3. **A** Non-enhanced axial CT brain showed diffuse SAH with main cast at the anterior interhemispheric fissure, **B**, **C** preoperative CT angiogram volume rendering 3D reformate showed a small narrow neck AcomA aneurysm directed anterosuperiorly with the following dimensions (3.0 × 2.0 × 2.6 mm), **D**, **E** preoperative A–P view and working view angle DSA showing the AcomA aneurysm before coiling, **F** preoperative DSA working angle view showing the microcatheter inside AcomA aneurysm before coiling, **G**, **H** post-coiling (under GA) working angle view and A-P view DSA showing complete aneurysm obliteration (CO), **I** axial source image MRA 6-month FU showing stable aneurysm obliteration, **J**, **K** postprocedural 6-month FU MRA 3D volume rendering transparent formate that showed stable complete aneurysm obliteration (CO), **L**, **M** 1-year FU DSA Rt. ICA A–p view and left ICA working angle view that showed stable complete obliteration (CO), **N**, **O** 3-year postprocedural FU MRA 3D volume rendering transparent formate that showed stable complete aneurysm obliteration (CO).

However, the VER in patients who were operated under local anesthesia was [26.05 ± 8.4] less than those who were operated under GA [30.44 ± 15.2] without statistically significant difference between both groups (Table 2).

The initial angiographic results showed that complete obliteration [CO] was achieved in 12 patients (34.3%) as in (figs. 1 and 2) while incomplete obliteration was detected in 23 patients (65.7%) as the presence of neck remnant [NR] in 19 (54.3%) and body filling [BF] was found in 4 patients (11.4%) with a higher rate of complete occlusion in patients who were operated under local anesthesia, yet without a statistically significant difference between groups. This could be attributed to the operator as cases under local anesthesia were operated by senior interventionalist to decrease the time of the procedure which was not in cases who were operated under GA (Tables 2 and 3).

Despite the impact of location on the probability of aneurysm recurrence after coiling, there is still controversy as several studies showed no significant difference between anterior and posterior circulation aneurysm recurrence [12]. Other studies conducted exclusively on posterior circulation aneurysms indicated higher incomplete obliteration, late recanalization, with higher rates of retreatment [13], while in the current study, all studied aneurysms were limited to the anterior circulation only.

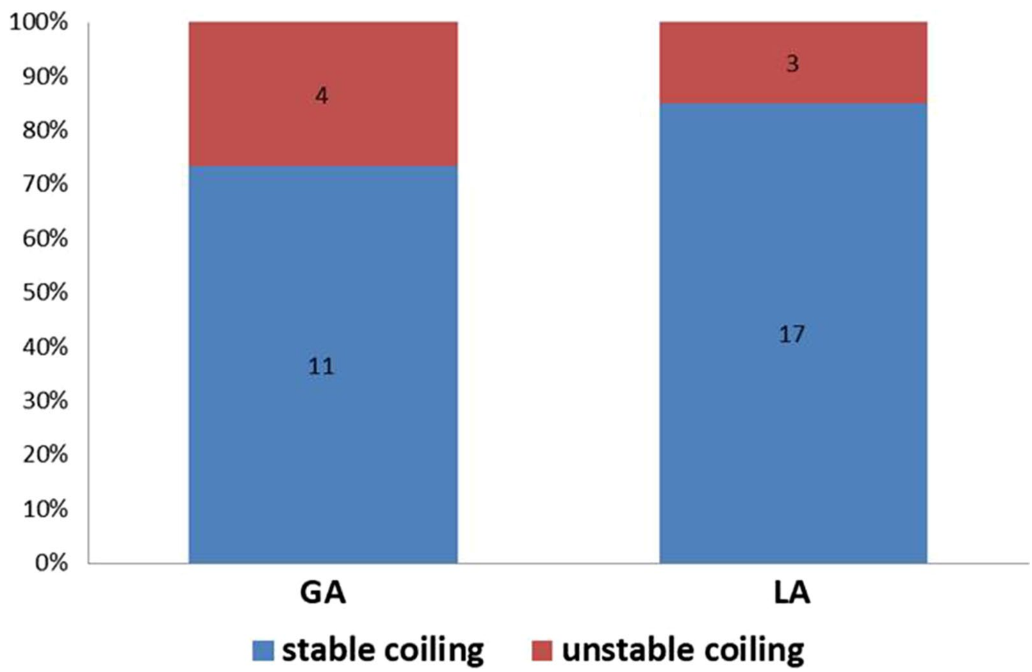

Fig. 3 Aneurysm obliteration in patients who were operated under LA and in patients who were operated under GA

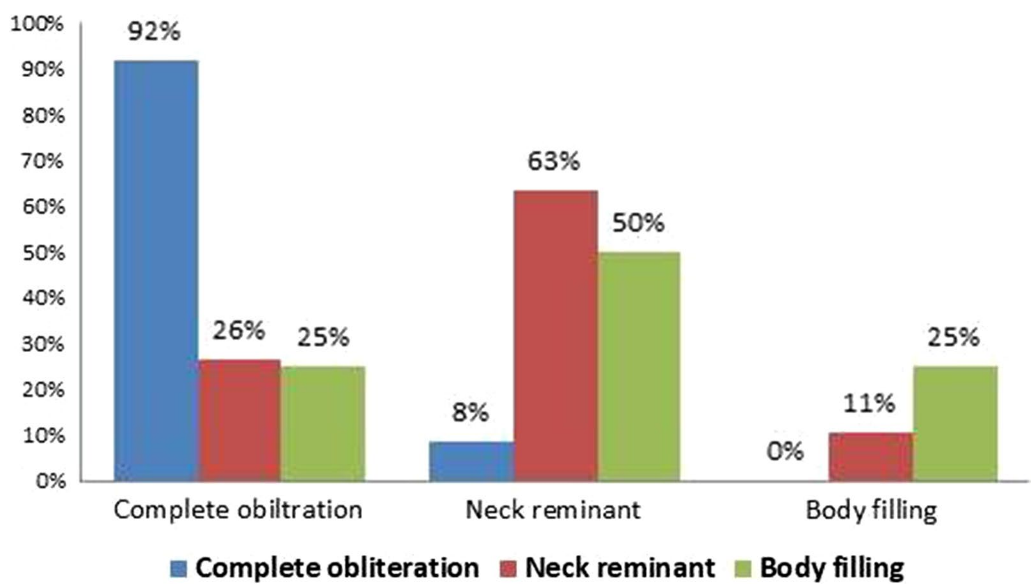

Fig. 4 Aneurysm stability at 1-year follow-up in relation to the initial control angiogram

In this study, the end-point was 1-year angiographic follow-up; although most of the aneurysms adequately occluded at 6-month angiographic follow-up will continue to stay completely obliterated on later FU, so prolonged imaging follow-up within the first 5–10 years after endovascular treatment might not be beneficial [33]. Also, a very low incidence of aneurysm re-bleeding was observed after the first year in the CARAT and ISAT studies [34].

The follow-up angiography at 1 year showed that complete obliteration [CO] has been achieved in 17 patients (48.6%) while incomplete obliteration was detected in 18 patients (51.4%) as the presence of neck remnant [NR] in 15 (42.8%) and body filling [BF] was found in 3 patients

(8.6%). No statistically significant difference was found between both groups regarding the 1-year follow-up complete aneurysm obliteration (Tables 2 and 3).

Stability of the aneurysm obliteration was detected in 28 patients (80%) without any statistically significant differences between both patients' groups; as stability in patients who were operated under LA was 85%, while stability for those who were operated under GA was 73.3% [$P=0.39$] (Fig. 3).

Aneurysm stability at 1-year follow-up was detected in 92% among those with CO at the initial control angiogram, while it was a bit less than 89% with initial angiographic results of NR (Fig. 4, Table 3) without any statistically significant differences between the study groups (Table 2).

Aneurysm recurrence after endovascular coiling has been reported in a wide range of treated cases (15–34%)22,32,34, while in our study, out of 31 successful initial aneurysm coiling, only 3 aneurysms (9.7%) showed recurrence at 1-year FU angiogram as all our cases included in the study were small aneurysms except one.

Few complications were encountered in this study; one case of intraprocedural rupture without any consequence that has been managed instantaneously by double catheter technique (LA group), and one case of femoral sheath-related hematoma that has managed conservatively (GA group), one case of minor thromboembolism that has been managed conservatively (GA group).

All cases except one were treated using a simple coiling technique, one case suffered intraprocedural rupture without any consequence that has been managed instantaneously by double catheter technique and the aneurysm was closed well with resultant persistent NR (LA group).

Although our pilot study was carried out with a small number of cases, it showed that endovascular coiling of intracranial aneurysms in awake patient appears to be safe, feasible and allows intraprocedural evaluation of the patient but interventional neuroradiology procedures can be difficult, and stressful for patients in addition to the fact that patients with neurological injury may be confused and are noncooperative [28, 29].

Limitation of the study

This study has potential limitations including the small sample of patients whether operated under LA or under GA. All the studied patients were located in the anterior circulation, and all patients except one had small aneurysms with a mean aneurysm size of 5.6 mm.

Conclusions

Endovascular coiling of cerebral aneurysms under local anesthesia is a safe and feasible procedure to be done by well-trained hands when the procedure is expected to be short.

Abbreviations

VER	Volume embolization ratio
GDC	Guglielmi detachable coil
LA	Local anesthesia
GA	General anesthesia
CO	Complete aneurysm obliteration
SD	Standard deviation
NR	Neck residual
FU	Follow-up
BF	Body filling

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Author contributions

HE has participated in performing the procedures, helped in writing and reviewing manuscript and data collection. SA and MA have participated in writing and reviewing manuscript and data collection. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol was formally reviewed and approved by Research Ethics Committee (REC) number (FWA 000017585) FMASU R 94/2022.

Consent for publication

Informed consent was obtained from the patients included in this study.

Competing interests

The authors declare that there are no competing interests.

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