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Role of preoperative computed tomography angiographic anatomical considerations and their intraoperative interpretations in prediction of outcome in microsurgical clipping of ruptured anterior communicating aneurysm

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Abstract

Background: Anatomy of anterior communicating vascular complex is variable and sometimes causes troublesome situations during microsurgical clipping of ruptured anterior communicating (Acom) aneurysms. Preoperative understanding of anatomy, expecting the presence of normal variations, knowing the exact aneurysm morphometrics and understanding flow dynamic patterns, help to reach an appropriate surgical outcome.

Methods: We analyzed the preoperative angiographic anatomical findings in computed tomography angiography and compared them to the intraoperative microscopic anatomical finding in 52 patients who underwent microsurgical clipping of ruptured Acom aneurysms, to reach angiographic prognostic factors in ruptured Acom aneurysm surgery.

Results: There is statistically significant relation between intraoperative anatomical factors and preoperative CTA findings (closed A2 aneurysm angle, neck extending to A2, anatomical variation, hypoplastic A1, and posterior projection).

Conclusion: CTA is a reliable method to predict the intraoperative anatomy in Acom aneurysm clipping. Poor outcome was more common among cases with posterior projection, closed A2-aneurysm angle, aneurysm neck extension to A2, and hypoplastic A1.

Keywords: Aneurysm, Computed tomography angiography, Anterior communicating artery

Introduction

Anterior communicating (Acom) complex is the most common location of cerebral aneurysms with incidence 30% [1]. This particular location involves five main arterial structures (ipsilateral A1, ipsilateral A2, contralateral A1, contralateral A2, and Acom artery), in addition to related arterial branches: recurrent artery of Heubner, orbitofrontal artery, frontopolar artery, and perforators [2]. This unique angioarchitecture, frequent anatomical variations, and deep interhemispheric location make microsurgical clipping of these aneurysms a very challenging process [2–4].

With regard to the relationships between aneurysm site and size, ruptured Acom aneurysms tend to be smaller than aneurysms located at other sites, suggesting that the rupture rate of Acom aneurysms is highest among cerebral aneurysms. It is thought that differences

Alawamry *et al. Egyptian Journal of Neurosurgery*   (2021) 36:5

Page 2 of 6

of 50% or more between two A1 segments result in more flow stresses leading to a higher risk of rupture in patients with Acom aneurysms [3, 5].

Digital subtraction angiography (DSA) remains the gold standard test to diagnose and plan the treatment for cerebral aneurysms; however, computed tomography angiography (CTA) has improved to a sensitivity of about 95% for detecting ruptured aneurysms, when compared to DSA [6].

Methods

Between January 2016 and December 2019, we admitted 69 patients with ruptured Acom aneurysm, to the Department of Neurosurgery in Zagazig University Hospitals, Egypt. We excluded 17 patients from this study, 10 patients who were treated with endovascular techniques, four patients presented with World Federation of Neurosurgeons (WFN) clinical grade more than grade three and 3 patients who were investigated initially by magnetic resonant angiography (MRA).

We included 52 patients with 52 ruptured Acom aneurysm, with WFN clinical grade three or less; all were investigated with preoperative cerebral 4 vessels CTA using 128 row multi-detector computed tomography "Philips Ingenuity core 128 ™ v3.5.7.25001" machine. All were treated with microsurgical clipping of ruptured aneurysm.

Time of surgery was based as early as possible principle; however, some patients were referred late to our center. We had early surgery (first 48 h of ictus) in 29 cases, and 13 cases had surgery within 14 days of ictus.

CTA protocol [7, 8]

All patients were examined on a 128-slice CT scanner (Philips Ingenuity core 128 TM v3.5.7.25001 machine) using a standard single-source examination protocol (none enhanced CT 120 kV, 380 mAs0, 64 × 0.6-mm collimation, 1-s rotation time, pitch 0.85; supraarotic CTA 120 kV, 190 mAs, 64 × 0.6-mm collimation, 0.33-s rotation time, pitch 1.0, 4-s delay after bolus tracking at the level of the ascending aorta with a weight-adapted contrast media injection protocol).

Axial images were reconstructed using identical parameters then the reconstructed axial images were sent to a workstation, and bone subtraction was performed automatically without any user interaction using a special application software. In the first step of post-processing, the two data sets (NECT and CTA data sets) are registered in a three-dimensional way, including translation and rotation on the basis of mutual information. In a second step, the application selectively eliminates bone from the CTA data set, while soft tissues as well as contrast-enhanced vessels remain for further evaluation. The resulting data set was stored in a standard DICOM format.

Image analysis was performed independently by experienced neuroradiologists. Besides the used reconstruction algorithm, bone subtraction, or standard reconstruction, no clinical data were provided to the readers for evaluation.

The technique of CT angiography includes delivery of an appropriate amount of iodine (iodine 350 nmol/ml) with injection rate of 5 ml/s. The use of a saline bolus is mandatory in our protocol to reduce streak artifacts due to beam hardening.
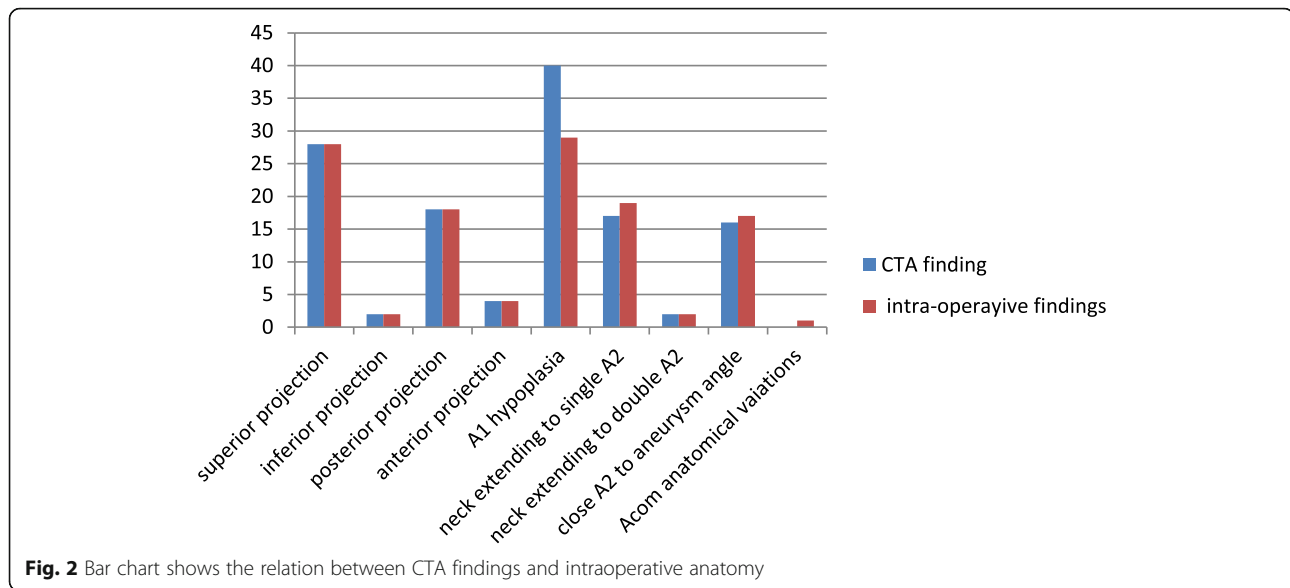
Three dimensional volume rendering is performed in workstation and based on transfer functions that require post-processing techniques with opacity values from 0 to 100%. For separation of different tissue types, color encoded trapezoids are used to enhance the discrimination between tissues.

We designed a checklist on reviewing the CTA findings (Table 1). Preoperative angiographic findings were reviewed by a neuroradiologist and a neurovascular surgeon, while the intraoperative microscopic anatomical findings were described by 2 neurovascular surgeons who performed and assisted the surgical procedure. Outcome was measured using modified Rankin scale (MRS) in immediate postoperative period and 6 months after treatment. MRS three or less considered as good outcome.

We followed Yasargil description to Acom aneurysm projections, five groups were described: superior, anterior, posterior, inferior, and complex projections. We drew a line through the ACom and parallel to the anterior skull base ("parallel line") on the sagittal plane of the 3D CTA; next, we drew a line perpendicular to the parallel line ("perpendicular line"). An aneurysm was defined as having anterior or posterior projections according to its positional relation to the perpendicular line. The projection was defined as superior and inferior according to its positional relation to the parallel line. Aneurysm morphology was described regarding neck size and sac diameter. We also described the angle (space) between aneurysm and both A2 (Fig. 1), with

Table 1 Checklist for CTA

Aneurysm morphometry
Neck size
Sac dimensions
Projection
Hypoplastic A1
Normal variations of Acom artery
Neck extending to ipsilateral A2 segment
A2-aneurysm angle
Opened
Closed (right–left)

Fig. 1 3D CTA showing Acom aneurysm; the angles drawn in red showing the open aneurysm A2 angle; here, easy aneurysm dissection and clip placement is expected

either open or closed angle. Dominant circulations from either left or right A1 were identified.

Results

We analyzed data of 52 patients with ruptured Acom aneurysm who underwent microsurgical clipping and were diagnosed by preoperative CTA.

CTA sensitivity and specificity: Table 2

We compared CTA anatomical findings checked in Table 1 to intraoperative anatomical findings (Fig. 2). We concluded that there is statistically significant relation between intraoperative anatomical factors and preoperative CTA findings (closed A2 aneurysm angle, neck extending to A2, anatomical variation, hypoplastic A1 and posterior projection).

CTA can diagnose closed A2 aneurysm angle with sensitivity 80%, specificity 100%, positive predictive value 100%, negative predictive value 88.9%, and accuracy was 92.3% in comparison to intraoperative findings.

CT can diagnose neck extending to A2 with sensitivity 90.5%, specificity 100%, positive predictive value 100%, negative predictive value 93.9%, and accuracy was 96.2% in comparison to intraoperative findings.

CT can diagnose hypoplastic A1 with sensitivity 100%, specificity 52.2%, positive predictive value 72.5%, negative predictive value 100%, and accuracy was 78.9% in comparison to intraoperative findings.

CT can diagnose posterior projection with sensitivity 100%, specificity 100%, positive predictive value 100%, negative predictive value 100%, and accuracy was 100% in comparison to intraoperative findings.

CTA prognostics in morbidity: Table 4

There is statistically non-significant relation between preoperative anatomical factors by CTA (closed A2 aneurysm angle, neck extending to A2, anatomical variation, and posterior projection) and postoperative morbidity.

There is statistically significant relation between preoperative anatomical factors by CTA (hypoplastic A1) and postoperative morbidity (sensitivity 16.7%, specificity 15.2%, positive predictive value 2.5%, negative predictive value 58.3%, and accuracy was 15.4%).

CTA prognostics in mortality: Table 3

There is statistically non-significant relation between preoperative anatomical factors by CTA (closed A2 aneurysm angle, neck extending to A2, anatomical variation, and posterior projection) and postoperative mortality.

There is statistically significant relation between preoperative anatomical factors by CTA (hypoplastic A1) and postoperative mortality (sensitivity 25%, specificity 18.8%, positive predictive value 2.5%, negative predictive value 75%, and accuracy was 19.2% in comparison to intraoperative findings) (Table 4).

Discussion

We wanted to assess the presence of anatomical prognostic factors in Acom aneurysm microsurgical clipping. We studied the relationship between presences of certain anatomical conditions that make the clipping process quite troublesome and clinical outcome. Those anatomical factors require more intraoperative dissection through the arachnoid planes and around aneurysm sac which might increase the risk of intraoperative rupture or postoperative ischemia. Also, we wanted to compare the anatomical findings in preoperative CTA to intraoperative microscopic anatomical findings.

Table 2 Performance of CTA in diagnosis of lesions among the studied patients

Findings	Sensitivity	Specificity	PPV	NPV	Accuracy	*p*
Closed A2 aneurysm angle	80	100	100	88.9	92.3	< 0.001
Neck extending to A2	90.5	100	100	93.9	96.2	< 0.001
Hypoplastic A1	100	52.2	72.5	100	78.9	0.002
Posterior projection	100	100	100	100	100	< 0.001

Fig. 2 Bar chart shows the relation between CTA findings and intraoperative anatomy

The reported sensitivity of CT angiography lies in the range of 80–97% depending on the size and location of an aneurysm [6, 9]. CTA provide data about related vascular structures and allows to simulate the intraoperative view during preoperative planning [10].

In our study CTA could not detect any anatomical variation in Acom artery, despite the presence of confirmed case with fenestrated Acom during surgery. That was consistent with previous studies that have shown a low prevalence for duplications and fenestrations in angiographic studies of 0.058% in one study and 0.48% in another study [11, 12]. Fenestration of the anterior communicating artery is seen more frequently in anatomic imaging studies than in angiographic evaluations [13].

Regarding projection, our study showed that CTA was 100% accurate in terms of prediction of aneurysm projection. We had posterior projection in 75% of mortality cases and 50% of morbidity cases. On their study, Kasinathan et al. had most intra- and postoperative complications with anterior and inferior projection. In relation to outcome, anterior, superior, and posterior projecting aneurysms had good results of 93.7%, 91.8%, and 88.4%, respectively, while patients with inferiorly projecting aneurysms had only 79.2% good results [14, 15].

Kasinathan et al. studied variations of A1 segment (including dominance of the A1 segment, as well as hypoplasia and absence of an A1 segment) in outcome of Acom aneurysm clipping and it had a direct relationship to postoperative anterior cerebral artery ischemia [14].

We used pterional approach in all cases, we evaluated the A2 aneurysm angle or what is called A2 fork in preoperative CTA, we commented on the angle either opened or closed as this is the dissection plane for aneurysm neck and the site where clip blades are applied, and unilateral gyrus resection was done in all cases and was enough to clarify the contralateral aneurysm-A2 angle and projection of contralateral A2 which is enough to have accessible distal control. Chen et al. described some cases where the access to the aneurysm neck was obstructed by the ipsilateral A1-A2 junction and the A2 segment. So this is where the interrelations between the plane of proximal bilateral A2, ACom, and the midsagittal plane, which was described by Chen et al. as the A2 fork orientation [16].

Hayashida et al. concluded that CTA is a reliable diagnostic tool for the preoperative evaluation of intracranial aneurysms. Their study was based on 320-detector CTA is highly useful for surgical treatment in most patients,

Table 3 Performance of CTA findings in prediction of postoperative morbidity among the studied patients

Findings	Sensitivity	Specificity	PPV	NPV	Accuracy	*p*
Closed A2 aneurysm angle	66.7	73.9	12	94.4	73.1	0.064
Neck extending to A2	50	65.2	15.8	90.9	63.5	0.656
Hypoplastic A1	16.7	15.2	2.5	58.3	15.4	0.001
Posterior projection	50	67.4	16.7	91.2	65.4	0.405

Alawamry *et al. Egyptian Journal of Neurosurgery*   (2021) 36:5

Page 5 of 6

Table 4 Performance of CTA findings in prediction of mortality among the studied patients

Findings	Sensitivity	Specificity	PPV	NPV	Accuracy	*p*
Closed A2 aneurysm angle	75	72.9	18.8	97.2	73.1	0.081
Neck extending to A2	50	64.6	10.5	93.4	63.5	< 0.001
Anatomical variations	0	100		98.1	98.1	
Hypoplastic A1	25	18.8	2.5	75	19.2	0.034
Posterior projection	75	68.8	16.7	97.1	69.2	0.114

although some small perforators deriving from the aneurysm may be missed [17].

On the other hand, Hirai et al. concluded that the aneurysm and surrounding vasculature may be more accurately evaluated with CT angiography than with catheter based angiography. Intraarterial CT angiography may not clearly demonstrate perforators or very small branches of the parent artery or aneurysms adjacent to the bone structures. Intraarterial CT angiography is a supplement to DSA. When an aneurysm is found or suspected at DSA, intraarterial CT angiography may demonstrate additional information that can affect patient treatment [18].

Limitations of the study
The use of 128 detector CTA did not allow the verification of perforators which has an important role in postoperative outcome. In our study, we depend on surgeon experience to verify, dissect, and preserve the perforators using microsurgical techniques.

Conclusion
CTA is a reliable method to predict the intra operative anatomy in Acom aneurysm clipping. Poor outcome was more common among cases with posterior projection, closed A2-aneurysm angle, aneurysm neck extension to A2, and hypoplastic A1.

Abbreviations
Acom: Anterior communicating; CTA: Computed tomography angiography; WFN: World Federation of Neurosurgeons; MRA: Magnetic resonant angiography; MRS: Modified Rankin scale

Authors' contributions
The authors read and approved the final manuscript. *AA*: participated in performing microsurgical clipping procedure, identification of intraoperative anatomy, and research idea owner and did most of the writing and statistical data analysis. *MT*: participated in performing microsurgical clipping procedure and identification of intraoperative anatomy and revised the article before submission. *TH*: participated in performing microsurgical clipping procedure and identification of intraoperative anatomy and revised the article before submission. *AAB*: CTA analysis and report writing. *MF*: CTA analysis and report writing.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
All patients agreed in written consent to participate in the study.
Study was approved by IRB committee in the Faculty of Medicine Zagazig University.
"Reference number is not applicable."

Consent for publication
Consent for publication was obtained from all participants.

Competing interests
The authors declare that they have no competing interests.

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