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ORIGINAL ARTICLE

Morphological characteristics of ruptured intracranial aneurysms: A comparative study between CTA and DSA

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ABSTRACT

Purpose: To study the agreement between digital subtraction angiography (DSA) and computed tomographic angiography (CTA) measurements on the aneurysmal neck and sac of ruptured intracranial aneurysms (IAs).

Material and Methods: Through a retrospective agreement analysis of all consecutive patients who reached our Tertiary Hospital with aneurysmal subarachnoid haemorrhage, we measured the intra-class correlation, Lin's concordance correlation and Bland-Altman analysis estimates on the maximal neck and sac diameters. We included patients who underwent both CTA and DSA in the period between 2012 and 2018. All CTA examinations were acquired using one of two CT scanners: a Toshiba Aquilion 16 CT scanner and a multi-detector Philips Ingenuity 128 CT scanner.

Results: Thirty-two patients (mean age of 55 years) and an equal number of IAs fulfilled our eligibility criteria. Most IAs (87.5%) were located at the anterior circulation. Based on CTA measurements, the inter-observer agreement of the CTA was "weak" regarding the neck diameter, and ranged from "strong"

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(2D-CTA) to "very-strong" (3D-CTA) regarding the sac measurements. Based on DSA readings, the 2D-CTA was more precise than 3D-CTA regarding the neck (overestimated by 0.91 mm and 0.94 mm, respectively) and the sac diameters (overestimated by 0.49 and 0.51 mm, respectively). Accordingly, the mean normalised smallest detectable differences (MNSDD) of 2D-CTA were 0.93 mm and 0.41 mm for the neck and sac, respectively. Likewise, the MNSDD regarding 3D-CTA were 0.93 mm and 0.36 mm for the neck and sac, respectively.

Conclusions: CTA is an imaging modality, which seems to describe the size of a ruptured IA sac accurately, but fails to delineate the morphology of the aneurysmal neck. CTA seems to overestimate the aneurysm neck, and thus, it is probably inferior to DSA in the decision-making process for the management of ruptured IAs of the anterior circulation.

KEY WORDS

Intracranial aneurysm/diagnosis; DSA; CTA; Observer variation

Introduction

Aneurysmal subarachnoid haemorrhage (SAH) is responsible for a significant disease burden throughout the world. The primary diagnostic and treatment goal for spontaneous SAH is the identification and complete occlusion of any underlying ruptured intracranial aneurysm (IA) [1, 2]. Several parameters may influence the decision making process regarding the most appropriate treatment strategy of each individual aneurysm. The anatomic location, the relationship of the aneurysm to the parent and any adjacent vessels, the size and the morphological characteristics of the aneurysm, the presence of an intra-cerebral haematoma, the patient's general medical status, the experience of the treating physician, the capability of the treating facility, as well as the patient's preference may have an impact on the selection of the final treatment plan [1, 2]. On confirmed SAH, computed tomographic angiography (CTA) is generally considered the next step, because it can reveal instantaneously, and with a high accuracy, any IAs. Reported sensitivity and specificity values of CTA in detecting an underlying IA range from 77% to 97% and 87% to 100%, respectively [3]. It has to be pointed out that CTA sensitivity for IAs greater than 5 mm has been reported to be as high as 100% [4, 5]. All of the above characteristics make CTA a valuable diagnostic tool in SAH patient evaluation.

Nevertheless, three dimensional rotational digital subtraction angiography (DSA) remains the gold standard examination for the identification and visualisation of any IAs [5–7]. However, it is characterised by some important drawbacks, including that is time consuming, not broadly available and expensive. In addition, it holds a measurable amount of side effects, ranging from 0.3% to 1.8%, since it is an invasive procedure [8]. It has to be mentioned however that this percentage is much lower in high-volume centers. All the recent advances in CTA have narrowed the employment of DSA as an initial diagnostic test, which is reserved for selected, challenging cases. There is a small body of evidence in the literature regarding the agreement between DSA and CTA in relation to the delineation of the inherent aneurysmal morphological characteristics. The primary goal of our study was to examine the agreement between DSA and CTA regarding the maximal diameter of the aneurysmal sac and neck. We hypothesise that CTA can be as accurate and precise as DSA in delineating aneurysmal morphology.

Material and Methods

Study design

We performed a retrospective agreement analysis in order to study the concordance of CTA measurements with the respective DSA values in elucidating the morphological characteristics of the studied IAs. Our Institutional Review Board (IRB) approved the current study. No participants' informed consent was required, since the study was based on retrospective anonymised hospital data. The reporting of our results was in accordance with the STARD-2015 [9] and QUADAS-2 [10] lists, used in diagnostic accuracy studies.

Patient selection

In this retrospective study, we have included all consecutive adult patients who were admitted at the emergency department of our facility with clinical suspicion of SAH. The diagnosis of SAH was established by obtaining a non-contrast head CT scan. CTA and DSA were obtained in all patients with an IA. Our study covered a 6-year period (from July 2012 to March 2018). Patients having poor quality images or only one of the two imaging studies were excluded from the study. Also, patients who were previously treated either endovascularly or surgically due to an IA in the past were omitted from our series.

Index test: CTA

All CTA examinations were acquired using one of two CT scanners: a Toshiba Aquilion 16 CT scanner and a multi-detector Philips Ingenuity 128 CT scanner. The scans extended from the body of C2 vertebra to the skull vertex, and were designed in the caudal-cranial direction during intravenous administration of 100 ml of non-ionic contrast material (370-400 mgI/ml). The intravenous injection of the contrast was followed by an infusion of 20 ml of normal saline (NaCl 0.9%) on a flow rate of 4-4.5 ml/s, using an 18-gauge needle into a peripheral arm vein. The bolus tracking technique was adopted by placing the region of interest on the aortic arch, while image acquisition was started when the attenuation reached the predefined threshold of 60 HU. The multi-slice CT angiographic data acquisition protocol performed on the 12 slice CT scanner were: collimation 64x0.625, pitch 0.8, slice thickness 1 mm, reconstruction interval 1x0.5 mm and acquisition parameters 120 kVp/215 mA. The protocol for the 16 slice CT scanner included: collimation 16x0.5, pitch 0.6, slice thickness 0.5 mm, reconstruction interval 0.5x0.5 mm and acquisition parameters 120 kVp/250 mA. Original and reconstructed images were both interpreted at the Philips Intellispace portal workstation. The post-processing analysis included standard axial, coronal and sagittal images, volume rendering, maximum intensity projection techniques and 3D reconstructions using the manufacturer's software.

We categorised the severity of haemorrhage according to the Fisher grade classification scale [11]. Two independent raters, including a specialised neuroradiologist with 20 years of experience (EK) and a senior radiology resident (MKK), performed the CTA measurements and evaluated all the parameters of interest. Both radiologists were blinded to the DSA results and recorded a bundle of aneurysmal morphological parameters, including the total number of aneurysms (if more than one), anatomical location, size and shape, 3-D orientation, as well as the sac and neck diameters.

Fig. 1. *Study flow chart. A total of 188 patients presented at our institution with spontaneous SAH during the study period, which were managed solely on non-invasive modalities (CTA or MRA). Both CTA and DSA were required for the management of 41 patients. Of these, we excluded 2 patients with missing data files, 3 patients with poor DSA image quality and 4 patients with poor CTA image quality. Ultimately, 32 patients with an equal number of IAs fulfilled our eligibility criteria and formed our study sample.*

Reference test-DSA

All eligible patients underwent DSA and the evaluation of the results was performed within 2 days after CTA. DSA was performed by a specialised neurosurgeon with endovascular training (APM), under general anaesthesia

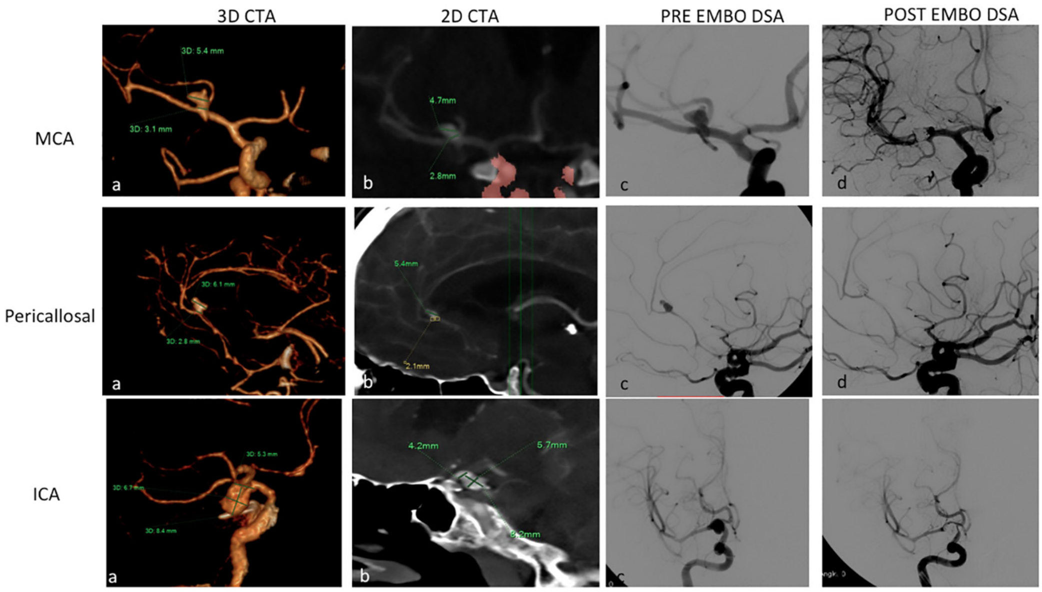

Fig. 2. *Three different patients. 3D CTA (**a**), 2D CTA (**b**) reconstructions and DSA pre (**c**), and post (**d**) embolisation of an MCA bifurcation (1st row), pericallosal (2nd row) and ICA (3rd row) aneurysms.*

via a femoral catheterisation using the Seldinger technique. A four vessel DSA, including antero-posterior, lateral and oblique views was performed in all patients. Selective catheterisations were performed in both internal carotid and vertebral arteries using non-ionic contrast media at a flow rate of 2 ml/s. The film rate was 2 frames/s for a total of 20 frames. Three-dimensional rotational angiographic images were also obtained and special projections were also performed looking for the working projection, in which the most detailed relationship between the aneurysm and its surrounding arteries could be detected. The maximal sac and neck diameter and their ratio were calculated. The neurosurgeon performing the DSA measurements was blinded to the CTA results.

Statistical analysis

Our statistics were based on complete-case analysis. All baseline characteristics were summarised using the mean and the standard deviation or median and their interquartile range for continuous variables, according to the distribution of the available data and on counts along with the percent estimate for discrete variables. The inter-rater agreement was estimated by the intra-class correlation coefficient (ICC) and its 95% confidence intervals [12], while the correlation between the two modalities was performed using the Lin's concordance correlation coefficient (CCC) and its 95% confidence intervals [13]. The results were supplemented by the bias and precision estimates, according to the Bland-Altman (B-A) analysis [12, 14]. In CCC and B-A analysis, we used the average value of the two CTA raters, in anticipation for inter-rater variability. We controlled for the assumptions of the B-A analysis by assessing the normality distribution of the between-studies differences according to the Shapiro-Wilk normality test and we visualised the results using density plots [15]. Finally, we estimated the mean normalised smallest detectable difference (MNSDD) for each pair of examinations. A B-A plot (also known as difference plot) in biostatistics is a method of data plotting used in analysing the agreement between two different modalities. It is used to compare a new measurement technique or method with a gold standard. The bias between the two tests is measured by the standardised mean of the differences [12, 14]. All statistical tests were performed using the statistical environment R [16].

Interpretation of the results

ICC values between 0.00-0.10, 0.10-0.39, 0.40-0.69, 0.70-0.89 and >0.90 indicated "negligible", "weak", "moderate", "strong" and "very-strong" inter-rater agreement, respectively [17]. Similarly, the CCC was interpreted according to the McBride proposal, with values less than

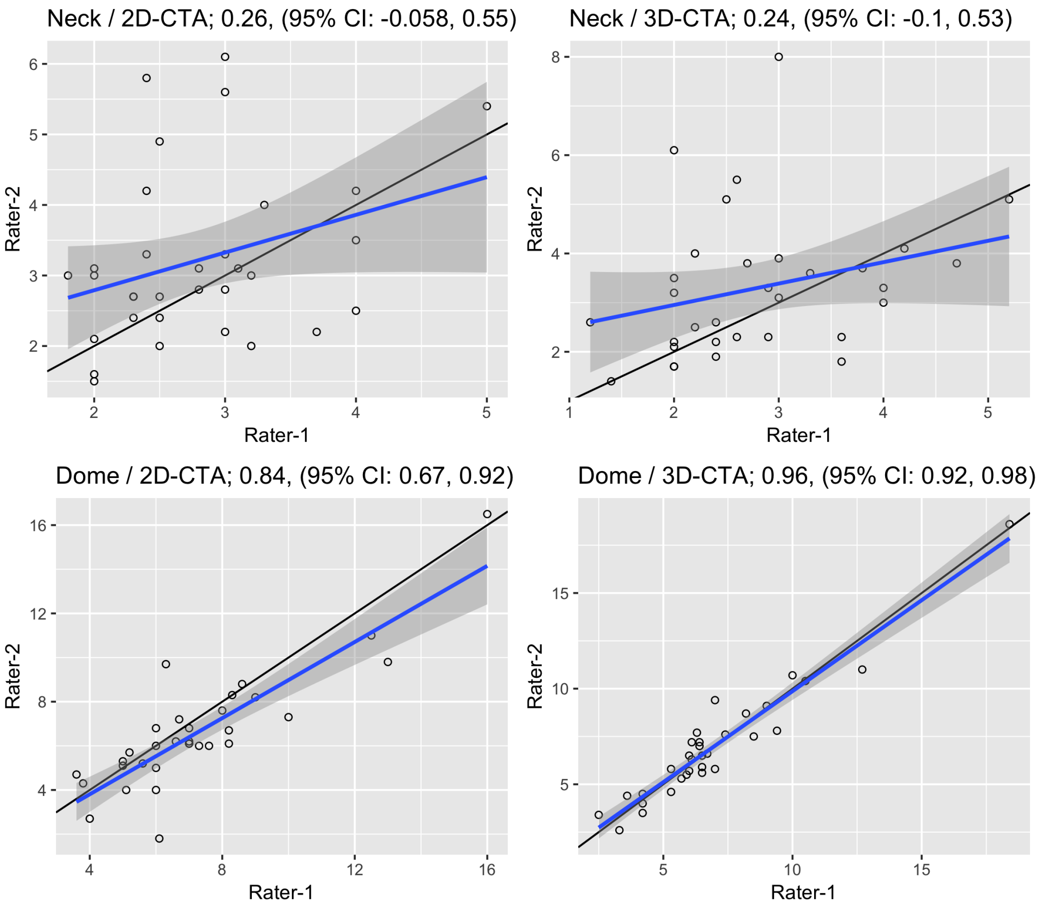

Fig. 3. The scatter plot depicts the inter-rater agreement in CTA for the morphology of intracranial aneurysms. There was a "strong" (2D-CTA) and "very-strong" agreement between the two raters on the maximal sac diameter. However, the agreement was estimated to be "weak" with respect to the maximal neck measurements.

90% corresponding to "poor", 90-95% to "moderate", 95-99% to "substantial" and >99% as "perfect" agreement [18]. We did not define any a priori set of cutoffs for the B-A bias and the maximal acceptable difference.

Results

Patient sample description

A total of 188 patients presented at our institution with spontaneous SAH during the study period, which were managed solely on non-invasive modalities (CTA or MRA). An IA was identified in 149 cases and 108 were managed with the use of either CTA or DSA alone. Both CTA and DSA were required for the management of 41 patients. Of these, we excluded 2 patients with missing data files, 3 patients with poor DSA image quality and 4 patients with poor CTA image quality. Ultimately, 32 patients (**Fig. 1**) with an equal number of IAs fulfilled our eligibility criteria and formed our study sample, including 15 males (47%) and 17 females (53%) with a median age of 55 years (IQR: 51-59 years) (**Table 1**).

In more than half of the cases (53%), the aneurysmal rupture was associated with severe aneurysmal SAH (Fisher Grade 4). All of the aneurysms were saccular with a measurable neck and sac (**Fig. 2**). The IA was located at the anterior circulation in 28 cases (87%), with the anterior communicating artery being the most common parent vessel, involved in 22 IAs (68.7%). Two aneurysms (6%) originated from the basilar artery, and 2 others (6%) from the posterior inferior cerebellar artery. According to the DSA measurements, the mean aneurysmal diameters were 2.11 mm (IQR: 1.65-2.5 mm) and 6.42 mm (IQR: 4.5-7.0 mm) for the neck and sac, respectively. The basic patient and aneurysmal characteristics are summarised in **Table 1**. The Toshiba Aquilion

Table 1. Summary of the main characteristics of our study participants

		Median	Interquartile range
Age (years)		54.88	50.75-58.50
Aneurysmal neck (mm)	DSA	2.00	1.65-2.50
	2D-CTA	2.88	2.50-3.40
	3D-CTA	3.00	2.33-3.68
Aneurysmal sac (mm)	DSA	5.75	4.50-7.00
	2D-CTA	6.92	5.33-7.85
	3D-CTA	6.94	5.53-8.05
Neck-to-sac ratio	DSA	0.38	0.25-0.45
	2D-CTA	0.44	0.38-0.52
	3D-CTA	0.48	0.33-0.62
		N	%
Gender	Female	17	0.53
	Male	15	0.47
Modified Fisher scale	0	2	0.06
	I	5	0.16
	II	3	0.09
	III	5	0.16
	IV	17	0.53
Location of aneurysm	Anterior circulation	28	0.89
	Posterior circulation	4	0.13
Parent vessel	AComA	22	0.69
	MCA	3	0.09
	PComA	2	0.06
	ACA	1	0.03
	BA	2	0.06
	PICA	2	0.06

(DSA, digital subtraction angiography; CTA, computerised tomographic angiography; AcomA, anterior communicating artery; MCA, middle cerebral artery; PcomA, posterior communicating artery; ACA, anterior cerebral artery; BA, basilar artery; PICA, posterior inferior cerebellar artery).

16 CT scanner and the multi-detector Philips Ingenuity 128 CT scanner were used in 24 and 8 cases, respectively. It is noteworthy that the DSA did not identify any additional aneurysms compared to the initial CTA examination among the 32 patients undergoing both imaging modalities.

Table 2. Correlation between CTA and DSA in aneurysmal neck and sac diameters and their ratio in our study

		Normality distribution of the Differences	Lin's Concordance correlation	Bland-Altman				Mean normalised smallest detectable difference
			Shapiro-Wilk test (p)	Coefficient (95% CI)	Bias (mm)	Upper limit of agreement	Lower limit of agreement	
Neck	DSA	2D-CTA	0.728	0.32 (0.05, 0.55)	-0.91 (-1.20, -0.61)	0.69 (0.18, 1.20)	-2.5 (-3.02, -2.00)	0.93 (0.72, 1.21)
		3D-CTA	0.946	0.41 (0.09, 0.66)	-0.94 (-1.23, -0.66)	0.60 (0.11, 1.10)	-2.49 (-2.49, -2.00)	0.93 (0.71, 1.22)
	2D-CTA	3D-CTA	0.078	0.67 (0.28, 0.87)	-0.03 (-0.29, 022)	1.37 (0.93, 01.44)	-1.44 (-1.89, -0.99)	0.46 (0.35, 0.59)
Sac	DSA	2D-CTA	0.800	0.88 (0.68, 0.94)	-0.49 (-0.96, -0.03)	2.03 (1.23, 2.84)	-3.02 (-3.83, -2.22)	0.41 (0.30, 0.54)
		3D-CTA	0.268	0.91 (0.83, 0.96)	-0.51 (-0.93, 0.10)	1.73 (1.11, 2.18)	-1.69 (-2.22, -1.16)	0.36 (0.28, 0.49)
	2D-CTA	3D-CTA	0.059	0.95 (0.91, 0.97)	-0.02 (-0.32, 0.28)	1.65 (1.70, 2.91)	-1.69 (-2.29, -1.09)	0.24 (0.18, 0.32)
Ratio	DSA	2D-CTA	<0.05*	0.24 (0.0, 0.45)	-	-	-	-
		3D-CTA	0.771	0.50 (0.26, 0.68)	-0.12 (-0.17, -0.07)	0.14 (0.06, 0.22)	-0.38 (-0.46, -0.30)	0.83 (0.73, 1.10)
	2D-CTA	3D-CTA	<0.05*	0.22 (-0.1, 0.49)	-	-	-	-

(2D, two-dimensional; 3D, three dimensional; CI, confidence interval)

Inter-observer agreement and Lin's concordance correlation

With regards to the maximal neck diameter, we estimated an ICC of 0.26 (95% CI: -0.058-0.55) and 0.24 (-0.1, 0.53) using 2D and 3D-CTA, respectively. Furthermore, an ICC of 0.84 (0.67-0.92) of 2D CTA and 0.96 (0.92-0.98) of 3D CTA was found regarding the maximal sac diameter. Thus, the inter-rater agreement was "weak" in the neck diameter measurements, irrespective of the employed modality, while it ranged from "strong" (2D-CTA) to "very-strong" (3D-CTA) in the evaluation of the aneurysmal sac diameter (**Fig. 3**).

The CCC was estimated to be as low as 0.32 (0.1-0.5) and 0.40 (0.19-0.58) for the maximal neck diameter, using 2D and 3D-CTA, respectively. The equivalent values for the sac were 0.88 (0.78-0.94) and 0.91 (0.83-0.96) using 2D and 3D-CTA. Thus, there was an overall "poor" agreement between CTA and DSA in terms of the neck size, and a "moderate" agreement for the aneurysmal sac diameter (**Fig. 4**). There was a "poor" concordance between the 2D- and 3D-CTA measurements, in respect to the neck size (CCC: 0.67; 0.44-0.62), but a substantial agreement regarding the sac measurements (0.95; 0.91-0.97).

Bland-Altman's analysis

The Shapiro-Wilk normality test showed that the differences between the studied pairs of examinations followed a normal distribution, except for those between DSA and 2D-CTA and the 2D-CTA and 3D-CTA for the neck-to-sac ratio. The maximal neck and maximal sac diameter bias of 2D-CTA was -0.91 mm and -0.49 mm, respectively. Similarly, the maximal neck and maximal sac diameter bias of 3D-CTA was -0.94 mm and -0.51 mm, respectively. The differences between CTA and DSA measurements were normally distributed (**Fig. 5**). Moreover, the upper and lower limits of agreement are described in **Table 2** and plotted in **Fig. 6**. The mean normalised smallest detectable differences (MNSDD) of 2D-CTA were 0.93 mm and 0.41 mm for the neck and sac,

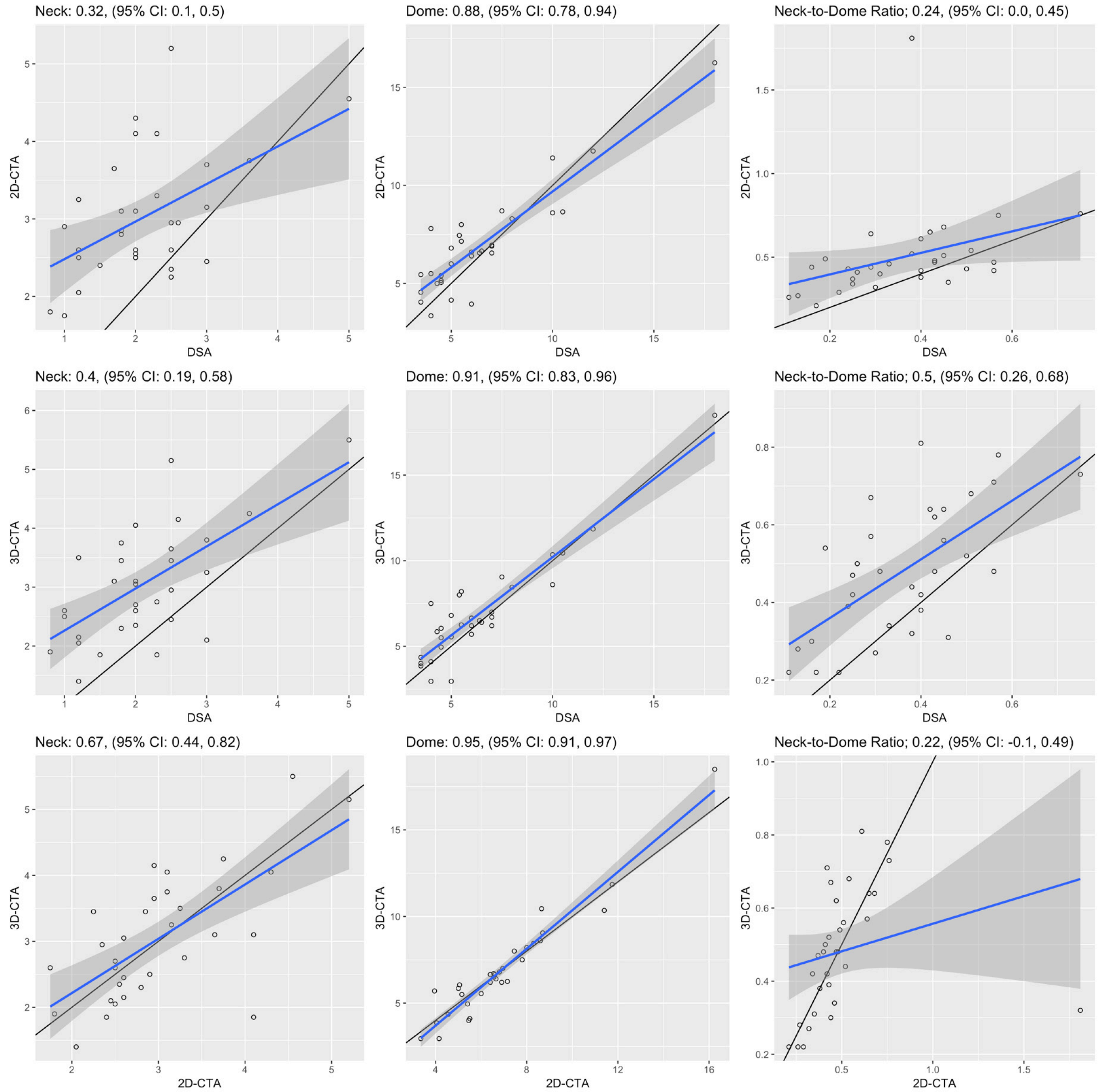

Fig. 4. *The plot depicts the Lin's concordance correlation between computerised tomographic angiography (CTA) and digital subtraction angiography (DSA). There was a "poor" and "moderate" agreement between CTA and DSA regarding the aneurysmal neck and sac, respectively.*

respectively. Likewise, the MNSDD regarding 3D-CTA were 0.93 mm and 0.36 mm for the neck and sac, respectively.

Discussion

Overview of results

The current study appraised the value of CTA in measuring basic intrinsic morphological characteristics of IAs, including the maximal neck and sac diameters. To the best of our knowledge, this is the first agreement study which considers the morphological characteristics as continuous variables, rather than a dichotomous parameter. As a result, there is no predefined cut-off value for aneurysm detection, any sensitivity and specificity issues, and we can measure the MNSDD. Moreover, CTA was characterised by a "high" inter-observer agreement considering the sac diameter measurement, but "poor" agreement regarding the neck diameter. Subsequently, we compared CTA to DSA and concluded that CTA was reliable in measuring the size of the

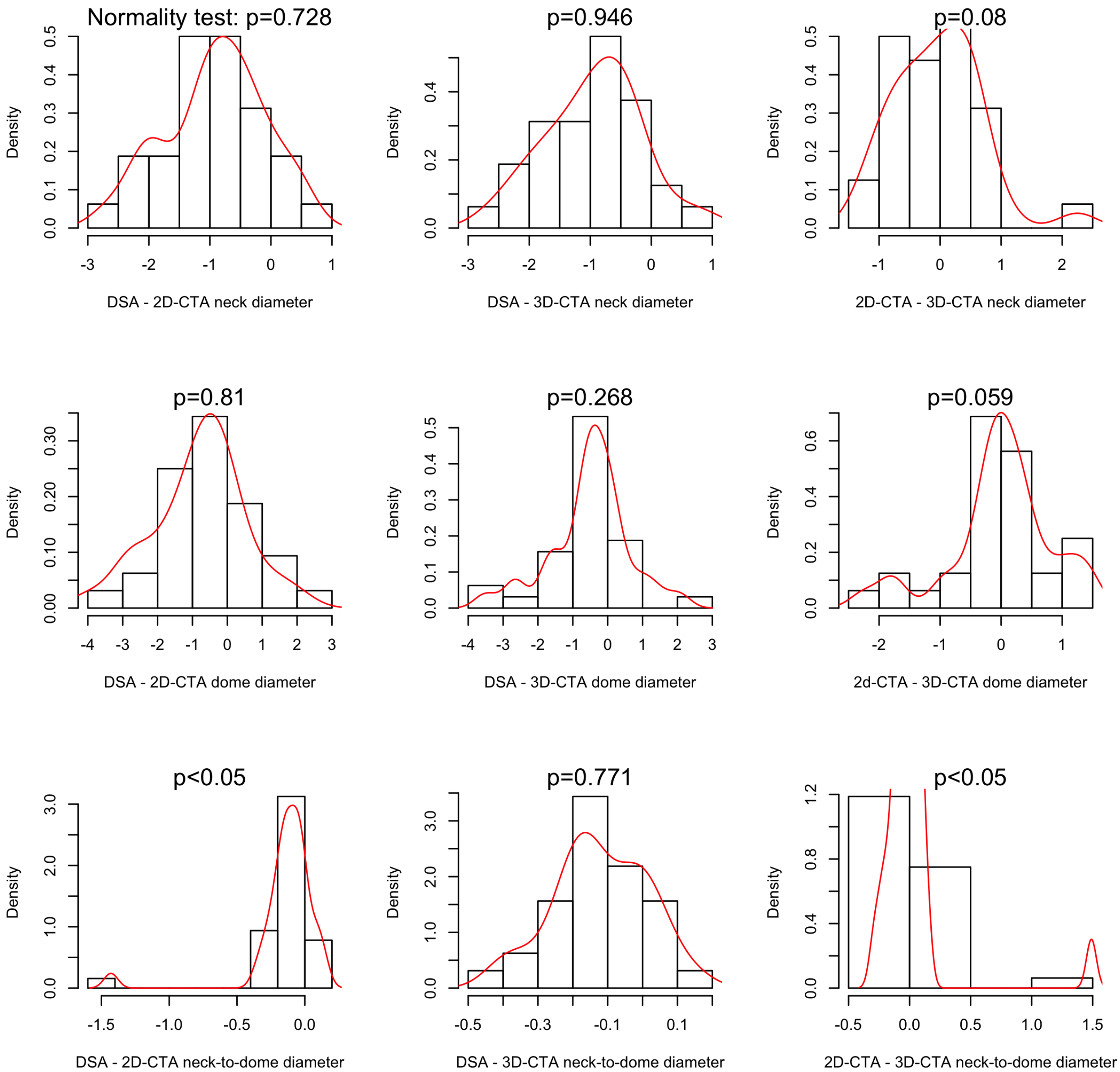

Fig. 5. *Controlling for Bland-Altman analysis assumptions: Histograms and density plots of computerised tomographic angiography (CTA) measurements, along with the p-value of the Shapiro-Wilk normality test for the differences for each pair of measurements.*

sac, but inaccurately estimated the neck's diameter and thus its relationship to the parent vessel. Finally, we found that CTA overestimated the maximal sac and neck diameters by approximately 0.5 mm and 1 mm, respectively. Overall, CTA (both 2D and 3D-CTA) was able to detect differences as small as 0.9 mm and 0.4 mm for the aneurysm's neck and sac, respectively. Thus, CTA was sufficient in delineating the sac of the aneurysm, but failed to accurately describe the neck of the aneurysm. This may have a significant impact on the decision making process of selecting the most appropriate therapeutic approach for each patient. Overestimation of the aneurysm neck may inappropriately characterise an aneurysm as non-amenable to endovascular thera-

Fig. 6. *Bland-Altman plots. Computerised tomographic angiography (CTA) overestimated the aneurysmal maximal sac (by approximately 0.5 mm) and neck diameters (by approximately 1 mm) in comparison to digital subtraction angiography (DSA).*

py or delineate the need of extra supporting endoarterial devices that may not be necessary, exposing the patients to extra intraoperative risks. The above-mentioned differences might be attributed to the operator dependent character of both modalities, the "anatomical resolution" of each method and the post-processing analysis.

Background

Spontaneous SAH caused by the rupture of an IA is a catastrophic event, associated with high morbidity and mortality rates throughout the world [1, 2]. Despite the rapid improvement of technology and the development of new imaging techniques and therapeutic strategies, the overall functional outcome still remains poor [1, 2]. Awareness, early detection, and appropriate management are of paramount importance in improving the patient's neurological outcome [1, 2]. For several decades, patients suffering aneurysmal SAH were evaluated using conventional DSA, in order to detect an underlying IA and identify its morphological characteristics for treatment planning [1, 2]. Nowadays, there is a large amount of published data in the

Table 3. Summary of the main characteristics of eight studies focusing on the agreement between CTA and DSA results

Author (Year)	Period, country	No. of patients and aneurysms	Gender, age	CTA	Outcome	Statistics	Conclusions
El Khaldi (2007)[25]	2004-2006, Italy	130p, 133a	57 men, 73 women; 59.5 years	16 detector	Sac: maximal neck diameter (categorical) Neck: Neck diameter (categorical) N/S: continuous	Sensitivity, specificity, positive predictive value, and negative predictive value of CTA	The two techniques were in agreement in defining 48 aneurysms with a narrow neck and the 44 aneurysms with a wide neck
Lubicz (2007)[36]	2005-2006, Belgium	54p, 67a	17 men, 37 women; 55 years	64-row multi-section	Sac: maximal sac diameter (categorical) Neck: Neck diameter (categorical) N/S: ratio Branching vessels	Sensitivity, specificity, positive predictive value, and negative predictive value of CTA Kappa statistic	Sac: the inter-technique agreement was excellent for all of the CTA readers (0.823–0.883) Neck: the inter-technique agreement was good for all of the CTA readers (0.732–0.778) Possible branch: Reader-2 failed to identify these branches in 3 of 4 cases N/S: It was overestimated by all of the readers at CTA
Zhang (2010)[37]	2008	46p, 40a	24 men, 22 women; 53 years	Dual-energy	Sac: dichotomous, continuous, Neck: continuous	Sensitivity, specificity, positive predictive value, and negative predictive value of CTA Correlation coefficient	Dual-energy CTA had diagnostic image quality at a lower radiation dose than digital subtraction CTA and high diagnostic accuracy compared with 3D DSA in the detection of intracranial aneurysms
Donmez (2011)[24]	2006-2009, Turkey	112p, 164a	81 women, 47 men; 52 years	16-row multi-slice	Sac: categorical and continuous variable Neck: continuous	Sensitivity, specificity, PPV and NPV of CTA Kappa statistic Bland-Altman plot	MDCTA is equally as sensitive as DSA in the detection of intracranial aneurysms of greater than 3mm, and it also reveals 100% detection rate for ruptured aneurysms
Zhang (2012)[34] Prospective	2007-2010, China	71p, 84a NA	NA	64-Detector	Sac: dichotomous	Accuracy, sensitivity, specificity, PPV and NPV	Accuracy, 96.8%; sensitivity, 97.6%; specificity, 95.1%; PPV, 97.6%; and NPV, 95.1%. The diagnostic performance of 64-detector CTA did not improve much compared to 16-detector CTA for detecting small intracranial aneurysms

Chen (2014)[23]	2006-2013, China	452p,	163 men, 289 female; 54 years	64-Detector	Sac: dichotomous	Counts (percentage)	The information provided from the CTA in 451 cases (99.8 %) was sufficient to support the choice of treatment
Kim (2017)[6]	2013-2016, South Korea	30p, 33 unruptured a.	13 male, 20 female; 65.8 years	256-row multi-slice	Sac: continuous, Neck: continuous, Height: continuous	SD in percentage and intraclass correlation coefficient for inter-observer and intra-observer measurements	There were no noticeable differences between intra-observer and inter-observer variability in cerebral Aneurysm sizes measured using CTA and MRA. The neck dimension had higher intra-observer and inter-observer variability than the height and width of aneurysms.
Present study (2019)	2012-2018 Greece	32 p, 32 a	17 female, 15 male; 55 years	16-slice CT scanner and a multi-detector 128-slice scanner	Sac: continuous Neck: continuous N/S: ratio	Intra-class correlation, Lin's concordance analysis Bland-Altman analysis	2D-CTA and 3D-CTA provided accurate estimation of the aneurysmal sac

(CTA, computerised tomographic angiography; DSA, digital subtraction angiography; p, patients; a, aneurysms; MRA, magnetic resonance angiography; N/S, neck-to-sac ratio; NA, not available; PPV, positive predictive value; NPV, negative predictive value; SD, standardised difference).

relevant literature supporting that non-invasive imaging techniques, such as CTA or magnetic resonance angiography (MRA), appear to be equivalent to DSA for the detection of suspected IAs, the former being used as the first step towards the endovascular therapy which has become the first-line treatment worldwide. CTA is widely considered the initial imaging method to detect the presence of an IA in patients suffering spontaneous SAH [1, 2]. However, DSA still remains the gold standard in the diagnostic and therapeutic work-up of aneurysmal SAH [1, 2, 19-21].

Diagnostic accuracy and agreement

As there is always a cost of information in downgrading data (from continuous to ordinal or dichotomous) [15], a number of statistical analyses have been developed to study the agreement of two sets of measurements [22-24]. The term diagnostic accuracy is used for dichotomous data and includes estimates such as sensitivity and specificity, likelihood ratios, area under the curve (AUC) and predictive values [22-24]. Similarly, Cohen's Kappa and Cohen's weighted Kappa statistics are utilised for nominal and ordinal data, respectively, while ICC, CCC, and B-A analyses are reserved for continuous data [22-24]. The strength of the findings goes hand-in-hand with the type of the available data, with those arising from continuous data being superior to the equivalent of dichotomous [24, 25]. It is worth noting that the ICC is an estimate of the inter-rater agreement while using the same continuous metric. Similarly, CCC is a metric of the degree to which two pairs of observations fall along the 45-degree line through the origin of the Cartesian system, whose axis are formed by the measurements of the two raters [24]. Finally, B-A analysis is performed when studying the interchangeability of two measurements and provides the bias (mean of difference between the measurements) and the level of precision (upper and lower limits of agreement) between the two modalities [24]. The wider the limits of agreement are, the lower the precision is [24].

Comparison with the literature

The interest in comparing CTA against the "gold standard", DSA, in the diagnosis of cerebral aneurysms is not a novel concept (**Table 3**). In 2003, Chappell et al. performed a meta-analysis focusing on articles, which reported on prospective comparisons of CTA and DSA in the evaluation of patients suspected of harbouring cerebral aneurysms [26]. Based on data from 21 studies with a total of 1251 patients, the authors found a sensitivity of 0.933 (93.3%; range, 75.4–100%) and a specificity of 0.878 (87.8%; range, 0–100%) [26]. Several years later, Menke et al. performed a similar meta-analysis of 45 studies with a total of 3653 patients and they concluded that the diagnostic accuracy of CTA with 16- or 64-row multi-detector CT was significantly higher than that of single-detector CT, especially in detecting small aneurysms [27]. In another review including 50 studies, Westerlaan et al. reported that multi-detector CT angiography could be used as a primary examination tool in the diagnostic work-up of patients suffering SAH, with an estimated pooled sensitivity and specificity as high as 98% (95% CI: 97%-99%) and 100% (97%-100%), respectively [28]. In addition, Frankin and Yu et al. calculated the diagnostic accuracy of CTA compared to DSA in the detection of a residual or recurrent cerebral aneurysm after clipping. According to the authors the pooled sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, diagnostic odds ratio and AUC of CTA were as high as 71%, 94%, 9.39, 0.32, 28.32, and 0.856, respectively [29, 30]. Finally, in a comprehensive meta-analysis study by Chen et al., it was demonstrated that the diagnostic value of CTA for IAs was in accordance with that of MRA [31]. It needs to be emphasised that the reported CTA diagnostic accuracy in all the above primary and meta-analytic studies has been calculated with the consideration of the presence of the IAs as a dichotomous variable (present or absent, aneurysm >3 mm or aneurysm <3 mm).

Apart from screening, CTA is also capable of delineating the morphometric characteristics of the IAs, including the sac and neck diameters and the presence of daughter sacs and exiting branches. Proper evaluation of the latter properties permits the selection of the most suitable treatment option for each patient. Lubicz et al. assessed the reproducibility of the CTA results using a 64-multi-detector CT scanner [32]. They found that the inter-technique and inter-observer agreements were “good” and “excellent” in measuring the diameter of the aneurysmal neck (mean k: 0.753 and 0.779, respectively) and sac (mean k: 0.847 and 0.876, respectively). However, the neck-to-sac ratio was overestimated by all of the readers using CTA [32]. Their findings are in agreement with our current results. Similarly, Kim et al. aimed to determine intra- and inter-observer variability of CTA in measuring the neck and sac dimensions of IAs [6]. The authors compared findings on 256-row multi-slice CTA to 3D rotational DSA (3DRDSA) and reported that the size of the cerebral aneurysms measured on CTA was 1.13– 9.26% larger than that measured by 3DRDSA, although their differences were not statistically significant [6]. However, in another study, Zhang et al. reported excellent correlation between DSA and CTA findings regarding the mean maximum diameter of the aneurysmal sac and neck (r=0.969, 0.957, and 0.870; p<0.01) [33].

Study limitations

This retrospective study carries some important limitations, including assessment bias, which may influence the statistical power of our findings. Moreover, the measurements have been performed on two different CT scanners, which might potentially generate distinct medical images and may influence the measurement of morphological characteristics. Furthermore, even though DSA measurements are considered as the “gold” standard in estimating the IA’s morphological parameters, it still remains a subjective modality. Additionally, the limited size of our series may further compromise its statistical power. Likewise, the small number of eligible patients does not permit stratification of our results according to the anatomic location of the aneurysm. Besides, there is an obvious selection bias towards anterior circulation aneurysms.

Conclusions

In conclusion, CTA constitutes an imaging study which accurately describes the size of the sac of a ruptured IA, but seems to consistently overestimate the size of the aneurysmal neck. These findings were applicable to both 2D and 3D-CTAs in our current series. As a result, CTA seems to be inferior to DSA regarding the sac/neck ratio calculation, that is one of the factors affecting the decision making process for the management of IAs. The decision to select endovascular treatment should initially take into consideration that the neck size is overestimated on the obtained CTA and the selection of the treatment method should be primarily based on a thorough DSA study. Future studies should focus on the agreement analysis between CTA and DSA, using 128- slice or higher CT scanners. Moreover, larger series are important in delineating the exact role of CTA after stratification of patients, according to the anatomic location of the aneurysm. Similarly, the agreement between CTA and DSA findings should be prospectively evaluated in larger series of patients with ruptured or unruptured aneurysms and in the long term follow up of patients with clipped or coiled aneurysms. **R**

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Ethical approval

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Conflict of interest

The authors declared no conflicts of interest.

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