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Clinical Article

3-Dimensional computed tomographic angiography for use of surgery planning in patients with intracranial aneurysms

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Summary

Background. After subarachnoid haemorrhage (SAH) diagnostic evaluation of the underlying cause is warranted since the rebleeding rate is high. The objective of the study was to answer the question, whether 3-Dimensional computed tomographic angiography (3D-CTA) is able to accurately determine the surgical indications in patients with intracranial aneurysms.

Methods. After performing 3D-CTA the size of the aneurysm, direction of the aneurysmal dome, neck position and variants of the circle of Willis were analysed. Surgery was performed solely on CTA data in those cases, where the aneurysm was clearly visible. If the findings were negative or inconclusive, intra-arterial digital subtraction angiography (DSA) was also done.

Findings. Between January 2001 and December 2002 100 patients (68 F, 32 M) were examined and 123 aneurysms (86 ruptured and 37 unruptured) were diagnosed. All patients received CTA preoperatively and in 27 patients selective DSA was additionally performed. Postoperatively in 34 patients the operative result was checked by DSA.

A good correlation between CTA and the intra-operative findings was present in 92 of 100 patients. One aneurysm was not seen on CTA, but was on DSA. In four cases we could confirm DSA findings in CTA after re-evaluation of the data. In three cases neither CTA nor DSA clearly showed an aneurysm, but it was confirmed during surgery.

A good correlation between CTA and DSA was found in 60 of 61 patients (98%). The correlation between CTA and intra-operative findings was good as expected in 92 patients, in 5 patients an aneurysm was detected on re-evaluation. Only one aneurysm could not be demonstrated by CTA but in DSA.

Conclusion. CTA is less invasive, less time consuming, cheaper and easier to demonstrate the essential information regarding the aneurysm than DSA. We therefore recommend that following a careful analysis most aneurysms – 92% – can be operated solely on CTA data.

Keywords: CTA; SAH; intracranial aneurysm; DSA.

Introduction

After subarachnoid haemorrhage (SAH) diagnostic evaluation of the underlying cause is warranted since the rebleeding rate is high [19]. Definitive treatment of the aneurysm is crucial for the patient's outcome. Controversy still exists concerning the best diagnostic procedure. Digital subtraction angiography is invasive and time consuming, and complication rates for a neurological deficit are reported between 0.25 and 1 percent [7, 14, 43]. Furthermore, DSA may increase the risk of rebleeding, especially within the first few hours after a haemorrhage [24]. It has been demonstrated that 3-Dimensional computed tomographic angiography (3D-CTA) can reliably detect intracranial aneurysms. Some authors have even stated that the diagnostic ability of 3D-CTA is superior to that of DSA [30, 37, 42]. However few reports rely on 3D-CTA as the sole diagnostic and preoperative planning study [3, 4, 15, 29, 50].

The aim of this prospective study was to address the question, if 3D-CTA is able to replace DSA as the ''gold standard'' for pretreatment planning and to see whether clipping of aneurysms can be based on 3D-CTA alone.

Patients and methods

Between January 2001 and December 2002 100 patients (68 women and 32 men, range 22–86 years; mean 55.2 years) were entered into this study. Inclusion criteria for the prospective protocol of CTA replacing DSA were: 1) all patients with SAH confirmed by a noncontrast head

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computed tomographic scan; 2) all patients referred with symptomatic or asymptomatic unruptured aneurysms revealed by computed tomography, magnetic resonance imaging, or magnetic resonance angiography; 3) all patients with neurological symptoms or findings suspicious for intracranial aneurysm.

Exclusion criteria were: 1) patients with a known allergy to contrast medium, 2) patients with renal failure. Patients were divided in two groups. Group A had a SAH and group B had no SAH prior to diagnostics and treatment (Fig. 4).

3D-CT angiography was performed within 12 hours after admission, in most cases following the unenhanced CT scan.

A standard multislice CT (VOLUME ZOOM 4 +, Siemens Medical System, Erlangen) was used to obtain 3D-CT angiography data sets. 3D evaluation of the intracranial vessels was performed on a computer workstation (Virtuoso, Siemens Medical System, Erlangen). All parts of the vertebrobasilar system and the anterior circulation were interactively explored and assessed with respect to the presence of intracranial aneurysms. In addition, stereoscopic analysis, which is a routine application of the Virtuoso software, was performed in all patients for advanced 3D evaluation of all arterial segments.

A neuroradiologist, and at least two neurosurgeons, including the senior author, reviewed the 3D-CTA scans.

Data sets of 3D-CTA were classified as sufficient, if an aneurysm correlating to the SAH localisation was detected, and no further information regarding the aneurysm's anatomy for planning the surgical procedure was needed. In these cases patients underwent microsurgical treatment without additional DSA.

DSA was performed, 1) In a patient with confirmed SAH and no cerebrovascular malformation revealed by 3D-CTA, 2) following 3D-CTA, if an aneurysm was not clearly shown or in cases of unclear anatomy of the aneurysm's neck, or in the presence of giant aneurysms, if further information regarding haemodynamics were necessary for surgery.

The DSA was done as a four-vessel DSA, using multiple projections via a femoral percutaneus catheterisation. Oblique and ×2 to ×3 magnification views were routinely obtained to clarify the aneurysm's anatomy.

Ruptured aneurysms were treated surgically within 72 hours after the SAH. Each patient's clinical condition was classified on admission based on the Hunt and Hess scale [18]. For the classification of the severity of the SAH the Fisher grading system was used [8].

Digital photo pictures of the aneurysms were made during surgery and compared with the 3D-CTA data sets. The neurosurgeon was asked to state whether the preoperative evaluation of the aneurysm using the 3D-CTA reconstruction data correlated well with the intraoperative findings.

After surgery DSA was performed to check the surgical result and to rule out additional aneurysms. In cases when no preoperative DSA had been performed, the postoperative DSA was compared with the 3D-CTA data sets obtained prior to surgery to correlate the data sets in regard to the detection of additional aneurysms.

Results

From January 2001 to December 2002 100 patients with suspected aneurysms were entered into our study (84 patients with SAH (group A) and 16 without SAH (group B)).

All 84 patients in group A had SAH confirmed with a non-contrast head computed tomographic scan.

In group A, 57 patients (68%) were female, and the mean age was 55.2 ± 16.8 years (range, 22–86 yr). In group B, 11 patients (69%) were female, and the mean age was 55.4 ± 16.9 years (range, 25–86 yr). Hunt and Hess grades and Fisher scores are listed in Table 1.

Table 1. *Clinical presentations of Group A patients*

Group A (SAH positive)	
Hunt & Hess Grade	Patients (n = 84)
I	4
II	9
III	42
IV	23
V	6
Fisher Grade	Patients (n = 84)
1	7
2	15
3	57
4	5

Table 2. *Clinical presentations of Group B patients*

Group B (SAH negative)	
Symptoms	Patients (n = 16)
headache	4
dizziness	3
vision changes	3
incidental	3
N III palsy	2
movement disorder	1

Table 3. *Prospective 3D-CTA protocol, localisation of aneurysms*

Only CTA preoperative (n = 62) (*Group A*)		
Location	Ruptured aneurysm (n = 64)	Additional aneurysm (n = 12)
AcoA	26	
MCA	19	6
AcoP	9	1
Pericallosal	3	2
ICA-Bifurcation	2	2
PICA prox.	2	
PICA dist.	1	
BA		1
ICA superior	2	
Only CTA preoperative (n = 11) (*Group B*)		
Location	Symptomatic aneurysm (n = 11)	Additional aneurysm (n = 1)
AcoA	8	
MCA	2	
AcoP	1	
ICA-Bifurcation		1

AcoA Anterior communicating artery; *AcoP* posterior communicating artery; *AChoA* anterior choroidal artery; *BA* basilar artery; *ICA* Internal carotid artery; *MCA* Medial cerebral artery, *PeCalA* Pericallosal artery; *PICA* posterior inferior cerebellar artery; *Ophthalmic* ophthalmic artery; *SCA* superior cerebellar artery.

Table 4. *Prospective 3D-CTA and DSA protocol, localisation of aneurysms*

CTA + DSA preoperative (n = 22) (*Group A*)

Location	Ruptured aneurysm (n = 22)	Additional aneurysm (n = 8)
AcoA	6	2
MCA	3	3
AcoP	5	1
Pericallosal	1	1
ICA-Bifurcation	2	1
PICA dist.	2	
SCA	1	
AChoA	1	
ICA superior	1	

CTA + DSA preoperative (n = 5) (*Group B*)

Location	Symptomatic aneurysm (n = 5)	Additional aneurysm (n = 0)
MCA	1	
AcoP	1	
ICA-Bifurcation	1	
Ophthalmic	1	
ICA superior	1	

AcoA Anterior communicating artery; *AcoP* posterior communicating artery; *AChoA* anterior choroidal artery; *BA* basilar artery; *ICA* Internal carotid artery; *MCA* Medial cerebral artery, *PeCalA* Pericallosal artery; *PICA* posterior inferior cerebellar artery; *Ophthalmic* ophthalmic artery; *SCA* superior cerebellar artery.

Clinical presentations of the patients in group B are listed in Table 2. The majority of the aneurysms were located in the AcoA and MCA as shown in Tables 3 and 4.

In group A, 62 patients (74%) underwent surgical treatment of their intracranial aneurysm based on CTA alone without DSA and in group B, 11 patients (69%).

In two patients with SAH and no cerebrovascular malformation revealed by CTA, DSA was performed. In the first case DSA detected a 6 mm AcoA aneurysm. In the second case an ICA aneurysm was seen on DSA. After re-evaluation of the 3D-CTA and increasing the reconstruction pitch, the ICA aneurysm could be demonstrated on 3D-CTA as well.

Overall 27 patients underwent both CTA and DSA pre-treatment.

In group A, 22 patients (26%) with intracranial aneurysm revealed by 3D-CTA underwent pre-treatment DSA and in group B 5 patients (31%).

In 34 patients (34%) of both groups without initial DSA, DSA was performed after surgery to evaluate clip placement and search for additional vascular malformations. In all 34 patients no additional aneurysm was found in DSA after surgery.

Therefore in 61 patients we could compare data sets of 3D-CTA with conventional DSA (pre- or postoperative DSA) (Fig. 3).

In 26 patients who underwent DSA preoperative correlation of 3D-CTA and DSA was excellent (96, 3%) as shown in Table 4. In one patient (3, 7%) a six mm sized aneurysm of the anterior communicating artery was not detected by 3D-CTA, but seen in DSA (see above).

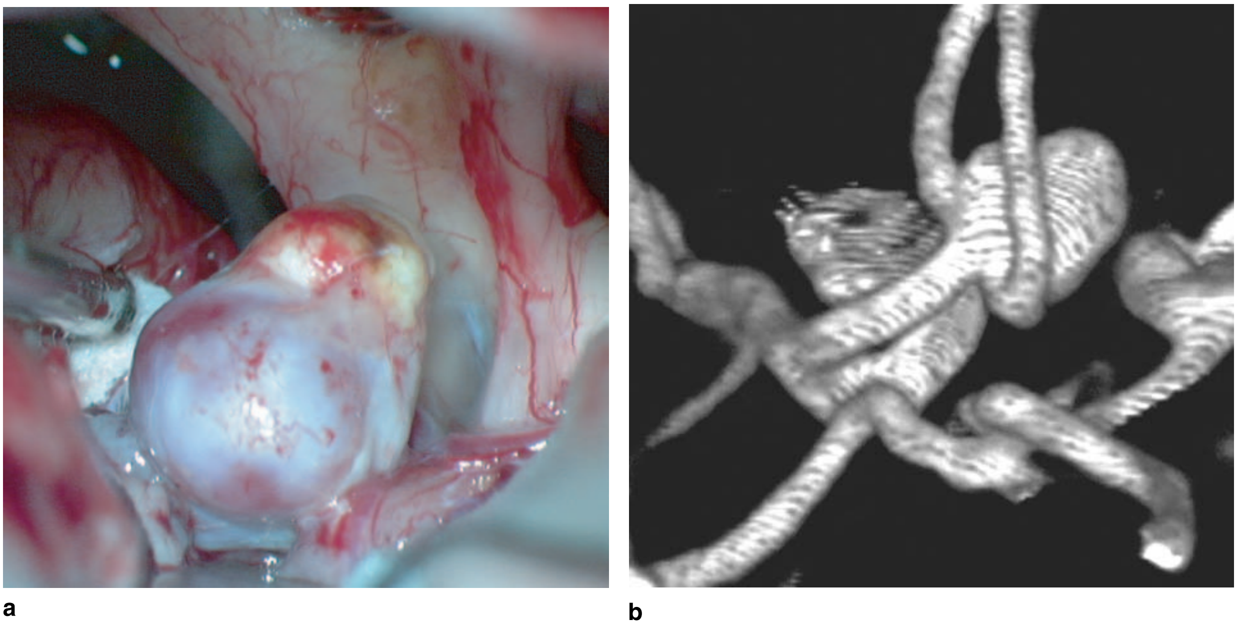

Fig. 1. Example of a 72-year old female, (Group A) showing a large (20 mm) AcoA aneurysm. 3D-CTA data (b) showing detailed information about the aneurysm's anatomy and regarding vascular structures. Intraoperative findings (a). *AcoA* Anterior communicating artery

When comparing the 34 data sets of 3D-CTA and postoperative performed DSA no additional aneurysms were detected by DSA.

In the 84 patients in group A CTA detected 91% of the ruptured aneurysms (77 aneurysms). In five patients 3D-CTA was judged to be without an aneurysm whereas DSA detected the aneurysm. Detailed examination of the data sets in 3D-CTA revealed the aneurysm in four cases (4, 8%), a question ruled out by the primary investigator.

In two cases neither CTA nor DSA clearly revealed the aneurysm. During surgery in both cases an aneurysm was clearly demonstrated and successfully treated.

Six baby aneurysms less than 2 mm neither detected by both diagnostic procedures were found and treated with coagulation during surgery. They were excluded from further analysis (not included in Tables 3 and 4).

In the 16 patients in group B CTA detected 16 of 17 (94%) aneurysms. In one patient with two unruptured aneurysms (MCA and ICA aneurysm) a small ICA aneurysm, (6%) could not be clearly identified, but intraoperative surgical findings verified the suspicion. No additional aneurysms were detected intraoperatively.

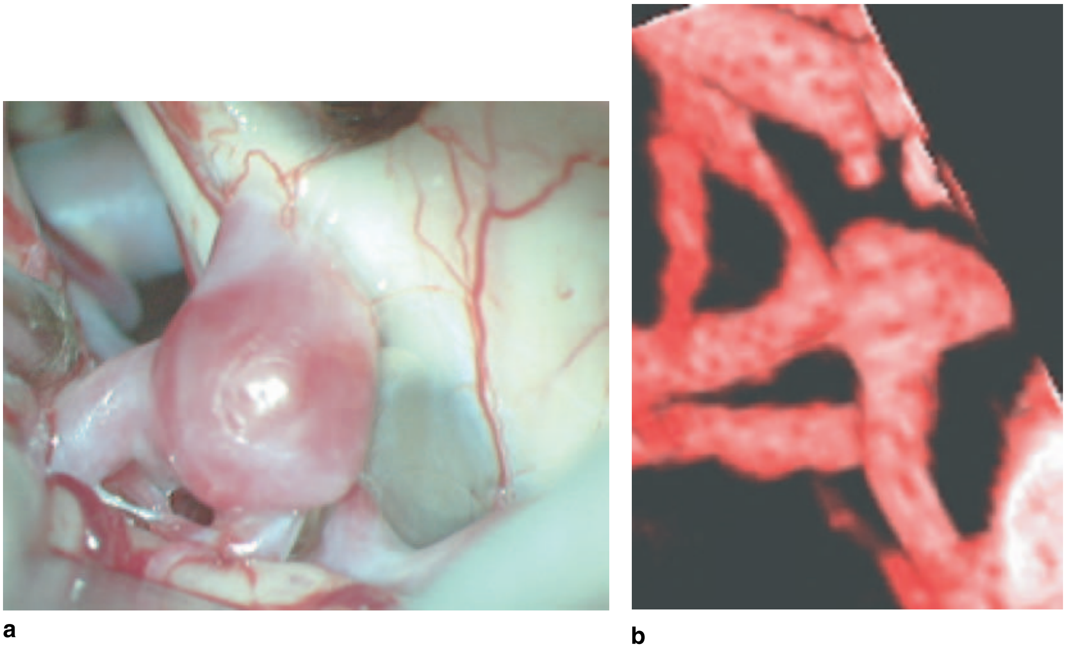

Fig. 2. Intraoperative findings (a) and 3D-CTA (b) of a 60-year old male with an AcoA aneurysm (Group B) showing the ability of 3D-CTA to reveal complex anatomy

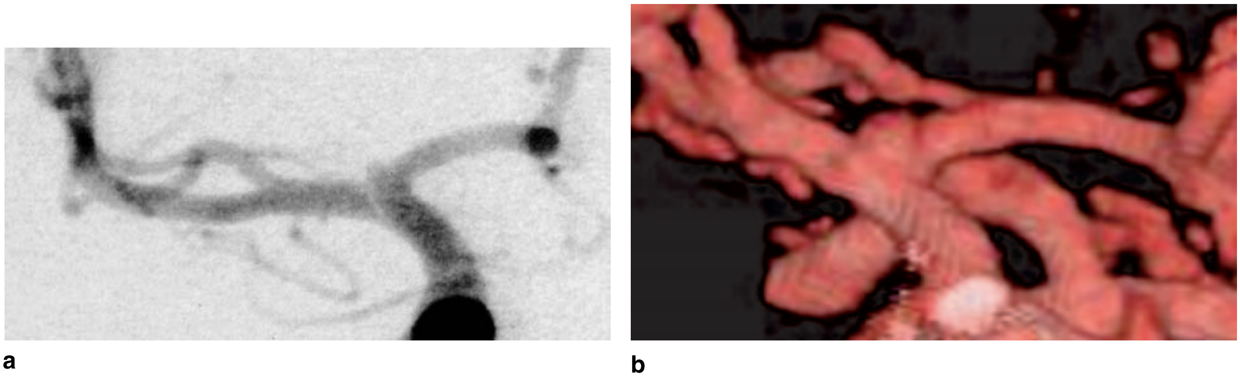

Fig. 3. DSA (a) and 3D-CTA (b) of a 23-year old male, Hunt and Hess Grade III, Fisher grade 3. 3D-CTA is showing an aneurysm of the ICA-bifurcation (4 mm). In this case DSA was performed additionally to confirm the 3D-CTA results. No further information was produced by DSA. *ICA* Internal carotid artery

In the group B patients who underwent pre or postoperative DSA no additional aneurysms were detected compared with the data sets of the CTA.

Eight additional aneurysms, detected by 3D-CTA, were confirmed in the preoperatively performed DSA. All six of the 13 additional aneurysms that were shown by 3D-CTA without preoperative DSA, were postoperatively confirmed by DSA. The other seven aneurysms could not be confirmed by DSA because the patients were not angiographically evaluated.

In order to further reveal the reliability of the 3D-CTA the preoperative data sets were compared with intraoperative findings. In all cases of confirmed aneurysms the intraoperative findings were judged by the surgeon to be in good correlation with the preoperative visualisation on 3-D reconstruction.

The additional comparison of the digital photo pictures with the preoperative 3D-CTA data sets showed a good correlation in all cases with the aneurysms anatomy (Figs. 1–2).

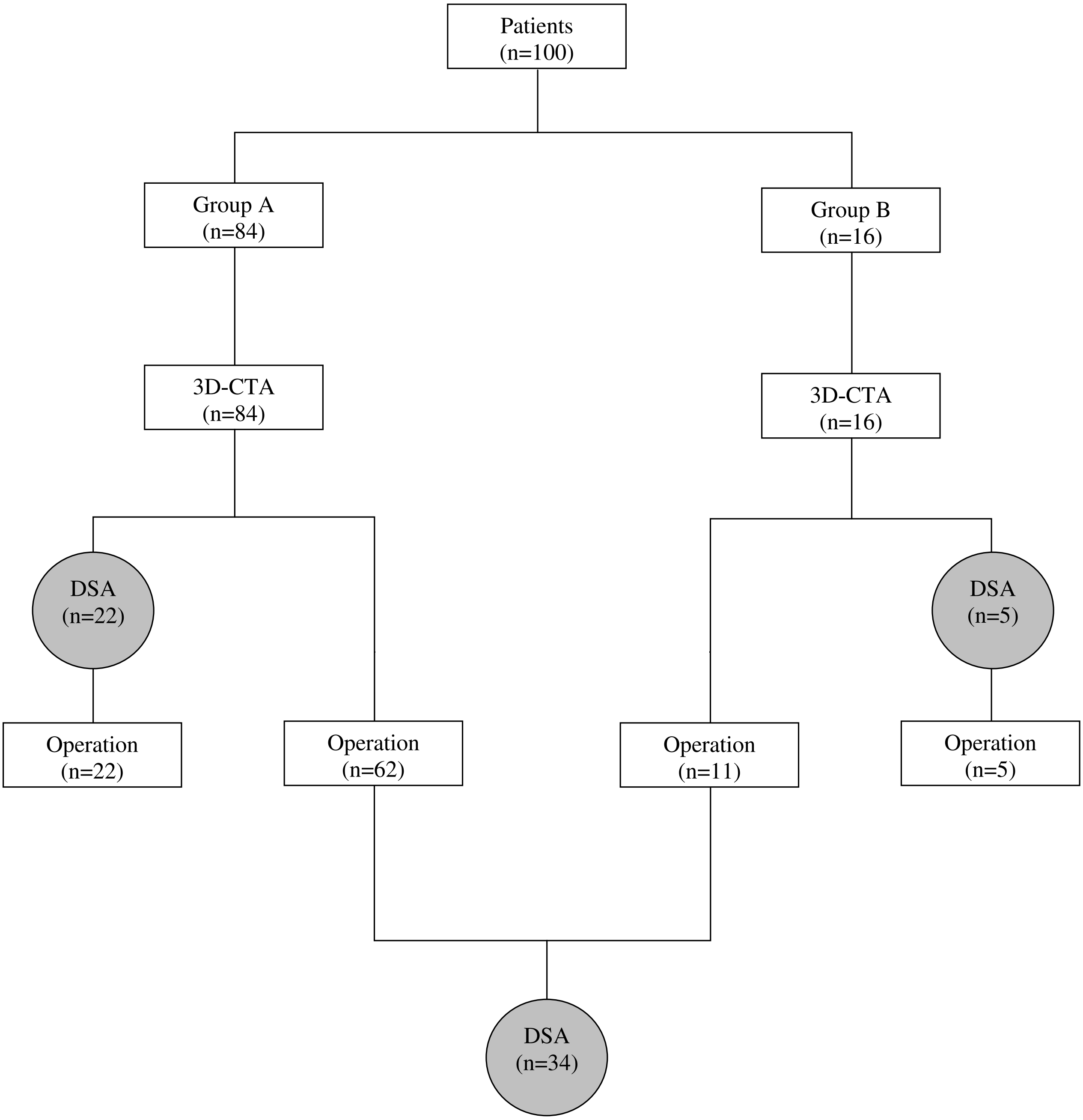

Fig. 4. Flow chart showing decisions and interventions in patients with suspicion for aneurysm

Table 5. *Clinical results*

GOS	Patients group A (n = 84)	Patients group B (n = 16)
Good recovery	26	12
Moderate disability	24	
Severe disability	14	
Vegetative	12	1
Death	8	3

In total, 62% of the patients showed a favorable clinical outcome (GOS V and IV) with no or moderate deficits after surgery (Table 5).

Discussion

CTA as a new diagnostic method in the detection of intracranial aneurysms was evaluated by many authors and found to be equal to DSA [1, 2, 5, 6, 11, 12, 16, 17, 25–28, 30, 32–41, 44–48]. Nevertheless, vascular neurosurgeons are divided into two groups: the first group uses DSA as a diagnostic procedure established over a long time and CTA as an additional diagnostic method and the other group consists of neurosurgeons, considering 3D-CTA without DSA sufficient for the detection of aneurysms and a diagnostic tool with a promising future**.**

In our study we wanted to settle the question, if CTA can replace DSA as primary diagnostic tool for the usual routine in the diagnosis of ruptured or unruptured aneurysms.

3D-CT angiography requires only a venous access and a small amount of iodine radiological contrast agent. The quick imaging modalities allow rapid diagnosis of the aneurysm soon after diagnosis of a SAH, because it can be done during the same radiological session [10]. Overall that will reduce the risk of complications caused by conventional angiography [1–3, 39]. The radiation dosage used in 3D-CTA is less than that for conventional angiography [9]. Furthermore, the cost of 3D-CTA is less than the cost of conventional angiography [29]. As in previous publications reported, 3D-CTA has been found to be superior to conventional angiography in displaying an aneurysm's shape or the relation to surrounding vessels and its anatomical variations [1, 3, 11, 12, 29, 30, 39, 42]. Gaining additional information of the adjacent skull and its relation to the aneurysm is possible. It is very easy to rotate the 3D-CTA data set to any angle that is needed to visualize the aneurysm in order to get important information regarding the neck and the dome of the aneurysm [3, 29, 30, 32, 35, 42].

Furthermore, useful surgical information, such as the presence of calcification, the position of the neck and its anatomical relation to the skull are provided [3, 29]. Possible surgical approaches and views of every side (including views from the bottom or the top) of the aneurysm can be obtained with 3D-CTA [29, 30, 42].

This ability helped us in planning and simulating the most favourable surgical approach especially in aneurysms of the AcoA. In these aneurysms the evaluation of the direction of the dome or the dominant ACA is essential for the correct approach. A number of investigators have stated that 3D-CTA sometimes can reveal an aneurysm that conventional angiography can not [6, 12, 17, 29, 50]. In our series there was no aneurysm detected by 3D-CTA that was not seen in DSA.

Aneurysm surgery solely based on 3D-CTA, data sets require a high sensitivity for detecting intracranial aneurysms. 92% of all patients in our study could be operated solely based on 3D-CTA data sets. Retrospectively, in addition 4% of the patients could have been treated, based on 3D-CTA alone since the aneurysms were visible on 3D-CTA if the examination was reconstructed differently. This improvement of diagnostic accuracy in our study suggests to our minds a learning curve.

Therefore, neurosurgeons and neuroradiologists with extensive experience with 3D-CTA will improve the diagnostic accuracy. With greater experience and practise the diagnostic sensitivity for smaller aneurysms will be improved as well.

Our results reveal a sensitivity of 92% (positive predictive value 100%, negative predictive value 83%) for detecting aneurysms with 3D-CTA and a specificity of 100%. In the literature other authors report similar results [28, 29, 39, 49]. Hoh *et al.* reported about a similar protocol for using 3D-CTA as the single diagnostic method for treatment planning, with a reported sensitivity of 100% for symptomatic aneurysms [15]. They also used DSA as an additional diagnostic tool, to answer questions about the anatomy of the aneurysm or in cases if no aneurysm was detected in patients with SAH.

Diagnostic evaluation for additional aneurysms seemed to be of similar accuracy, but statistical analysis was not done since seven patients did not undergo angiography either pre- or postoperatively.

In the literature a wide variation in regard to sensitivity (70 to 100%) and specificity (50–100%) of 3D-CTA for aneurysm detection exists [13, 29, 33]. Accountable for this maybe the two different generations of CT scanners used in the studies. Kato demonstrated the advantages of multi-slice helical 3D-CTA compared to single slice CTA [23]. These advances in the technology of multi-slice CT scanners resulted in increased image resolution. The superior image quality allowed a higher rate of detection of aneurysms with the use of a post-processing workstation.

Although it has been reported, that the limits of demonstrating small aneurysms in 3D-CTA can be up to 0.8 mm, in our series six baby-aneurysms that were below 2 mm in diameter were detected intraoperatively and not in 3D-CTA [28, 32]. This seems to be in accordance with other authors [1, 17, 27, 32, 35, 49].

Also small perforating arteries <1 mm, such as the recurrent artery of Heubner, the anterior choroidal artery, and thalamoperforating arteries, were not consistently visualized on 3D-CTA.

Further limitations of 3D-CTA are (partially) thrombosed aneurysms, as shown in our study. In a case of a thrombosis of the aneurysm 3D-CTA was judged as suspicious and DSA confirmed the suspicion. During surgery a partially thrombosed anterior communicating artery aneurysm, the perfused part 2 mm in size, was identified and coagulated. In another case a pericallosal aneurysm was >80% thrombosed, the perfused part about 3 mm in size, so that a distinct representation of the aneurysm was not present in 3D-CTA nor in DSA. In both cases surgery was performed on the basis of the typical blood distribution visible on CT scans. The procedure was also proposed by Karttunen for such circumstances [20].

Although it has been reported by many authors, that 3D-CTA is able to replace DSA in all but a few cases [3, 10, 22, 28, 29, 50] there are still just a couple of centres, where CTA is performed as the primary diagnostic tool in daily routine for planning aneurysm surgery [3, 4, 15, 39, 50]. The percentage of patients who have been operated solely based on 3D-CTA data ranges between 33% [4, 50] up to 93% [28]. Inspired by the reported accuracy of 100% and 96% in ruptured aneurysms we operated 68% of our patients solely on the basis of 3D-CTA findings [28]. Compared with other studies, this rate is higher [3, 4, 39, 50].

Conclusion

In our study we showed, that 92% of the patients with intracranial aneurysms could be operated solely based on preoperative 3D-CTA data sets.

In accordance with other authors we think that in the near future 3D-CTA could replace conventional angiography in most cases, especially if further optimising the soft- and hardware [15, 21, 22, 28, 31]. We would suggest DSA as an additional diagnostic method in treatment planning of aneurysm surgery only in special cases: If 3D-CTA does not show an aneurysm in patients with SAH, in cases with detected giant aneurysms, proximal ICA aneurysms or if other information about the aneurysms anatomy are needed, DSA should be used.

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Comment

This is a well written paper, set out to prove the today's CTA can replace catheter-angiography (DSA). This prospectively collected data set came from ruptured aneurysms (majority) and "innocent" aneurysms. However, it remains factual that in two-third of the cases, operations could be carried out based on CTA alone, and in one-third, catheter-angiographies were still requested.

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