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Complications in digital subtraction angiography: initial three years of experience

Dijital substraksiyon anjiografide komplikasyonlar: ilk üç yıllık deneyim

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Abstract

Purpose: In this study, we describe the complications we encountered during digital subtraction angiographies (DSA) in our initial three years of experience and evaluate the risk factors in our patient population.

Materials and methods: A series of 507 patients with different pathological processes were diagnosed via DSA in our institution from April 2019 through May 2022 and were retrospectively evaluated. During DSA, the date of the procedure, patient age, gender, comorbidities, catheter types, number of catheters used, and all procedure-related complications were recorded, even if they did not cause any neurological sequelae. Complications were categorized as neurological, non-neurological, or local.

Results: Our study included a total of 507 patients. Of these, 256 (50.5%) were male, and 251 (49.5%) were female. The mean age of patients was 49.2 years (range 5-91). The most preexisting comorbidity in patients was hypertension (22.5%). Of 507 patients, a total of 10 patients had either a neurological complication, radiological complication, or angio-site-related complication, and the overall rate of complications was 0.02%. In 6 patients with neurological complications, 3 (0.6%) had permanent neurological deficits, and 3 (0.6%) had transient deficits. In 4 patients with non-neurological complications, asymptomatic vasospasms were encountered in two cases; internal carotid artery (ICA) dissection was experienced in one case, and scrotal hematoma was observed in one case.

Conclusion: Complications following DSA are rare but must be minimized with knowledge of the characteristics of the patients and determining the proper indication. Although the risk is low, complications such as thromboembolism can cause permanent neurological deficits and even death.

Keywords: Digital subtraction angiography, neurological complication, non-neurological complication, catheter, vasospasm.

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Öz

Amaç: Bu çalışmada ilk üç yıllık deneyimimiz boyunca dijital substraksiyon anjiyografilerde (DSA) karşılaştığımız komplikasyonlar anlatılmış olup, hasta popülasyonumuzdaki risk faktörleri değerlendirilmiştir.

Gereç ve yöntem: Kurumumuzda Nisan 2019'dan Mayıs 2022'ye kadar farklı patolojilere sahip 507 hastaya DSA işlemi uygulandı ve sonuçlar retrospektif olarak değerlendirildi. Anjiyografi sırasında herhangi bir nörolojik sekel saptanmasa bile işlem tarihi, hastanın yaşı, cinsiyeti, yandaş hastalıkları, kateter tipleri, kullanılan kateter sayısı ve işleme bağlı tüm komplikasyonlar kaydedildi. Komplikasyonlar nörolojik, nörolojik olmayan veya lokal olarak kategorize edildi.

Bulgular: Çalışmamıza toplam 507 hasta dahil edildi. Hastaların 256'sı (%50,5) erkek, 251'i (%49,5) kadın olmakla beraber, ortalama yaşı 49,2 (5-91 arası) olarak saptandı. Primer patolojilere en çok eşlik eden hastalığın hipertansiyon olduğu görüldü (%22,5). 507 hastadan toplam 10 hastada nörolojik komplikasyon, radyolojik komplikasyon veya anjiyo bölgesine bağlı komplikasyon görüldü ve genel komplikasyon oranı %0,02 olarak bulundu. Nörolojik komplikasyon gelişen 6 hastanın 3'ünde (%0,6) kalıcı nörolojik defisit, 3'ünde (%0,6) ise geçici nörolojik defisit saptandı. Nörolojik olmayan komplikasyon gelişen 4 hastada iki olguda asemptomatik vazospazm, bir olguda internal karotid arter (İKA) diseksiyonu, bir olguda skrotal hematom gözlendi.

Sonuç: Dijital substraksiyon anjiografi esnasında komplikasyonlarla nadir olarak karşılaşılsa bile hastaların özelliklerinin bilinmesi ve uygun endikasyonun belirlenmesi ile komplikasyon oranı en az seviyeye indirilebilir. Risk oranının düşük olmasına ragmen tromboembolizm gibi komplikasyonlar kalıcı nörolojik defisitlere ve hatta ölüme neden olabilir.

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Anahtar kelimeler: Dijital substraksiyon anjiografi, nörolojik komplikasyon, nörolojik olmayan komplikasyon, kateter, vazospazm.

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Introduction

Efforts to visualize the vessels in the human body began with the discovery of X-rays by Roentgen [1]. In 1895, Haschek and Lindenthal obtained radiographs of blood vessels in cadavers. Afterward, Barberish and Hirsh began to visualize the arterial and venous system of the arm in 1923. Later, using a similar technique to Barberish and Hirsh, Brooks envisioned the blood circuit of legs [2, 3]. Finally, human intracranial circulation was successfully visualized by Egas Moniz in 1927 by using a radiopaque contrast agent [4]. Since then, with the improvements in catheterization techniques, injectors, subtraction, and magnification techniques, cerebral digital subtraction angiography (DSA) has been widely used to diagnose vascular abnormalities and cerebral pathologies and has become the gold standard imaging method to assess vascular pathologies [1, 5-11]. Although DSA was accepted as a safe way to visualize the cerebral vascular system, it is an invasive diagnostic tool and can cause complications [12].

The most severe complications caused by DSA are related to the neurological system. Although most neurological complications are transient, permanent neurological deficits can be seen because of cerebral infarction, and even death can be seen [13-17]. Large prospective series shows that permanent neurological complication rates change between %0.1-1.3 [18, 19]. Besides neurological complications, systemic and local complications such as contrast-induced allergy, contrast nephropathy, entrance side hematoma, amnesia, femoral artery occlusions, arterial dissections, or infections may seriously affect patients [15, 20-22].

In this study, we describe the complications we encountered during diagnostic cerebral angiographies during our initial three years of experience and evaluate the risk factors in our patient population.

Materials and methods

Patient data and outcome assessment

A series of 507 patients with different pathological processes were diagnosed via DSA in our institution from April 2019 through May 2022 and were retrospectively evaluated. The study did not include patients undergoing angiography as a part of interventional therapeutic procedures.

All patients underwent a detailed neurological examination at admission, during the DSA procedure, discharge, and follow-up. During the angiography, the date of the procedure, patient age, gender, comorbidities, and all procedure-related complications were recorded, even if they did not cause any neurological sequelae. Complications were evaluated as follows: neurological complications such as thromboembolism, intracranial hemorrhage, or ischemia, which generates new neurological signs or symptoms or worsening of preexisting deficit after the procedure; non-neurological complications which are radiologically revealed, such as asymptomatic vasospasm or dissection and local complications such as groin hematoma which are related to the puncture site.

Written informed consent was obtained from patients, implying that their medical records and images could be used for research in the future. The study was approved according to the ethical standards of the Declaration of Helsinki.

DSA technique

All angiographies were performed with the patient under local anesthesia or sedation via the femoral approach using Siemens Artis Zee monoplane angiography unit. Oxygen saturation and blood pressure levels were measured continuously. In our daily practice, internal carotid and vertebral arteries were selectively catheterized. Common carotid artery injections were performed before the selective catheterization. Selective catheterization was not performed in the presence of severe arterial stenosis or plaque. 5F catheters were routinely used for adult patients and 4F catheters for children.

A non-ionic contrast agent (Omnipaque 300, GE Healthcare) was used in all procedures. Two-dimensional diagnostic images were obtained using hand injections, but three-dimensional DSA images were obtained with pump injections. Catheters were intermittently flushed by hand with heparinized saline. At the end of the procedure, hemostasis was achieved by manual compression for 15-20 minutes. A 5 kg sandbag placed over the femoral artery puncture site in the leg and remain there for 6 hours. The patients were followed immobile for 6 hours.

Statistical analysis

Statistical analysis was performed to identify relations between preexisting comorbidities, indications for DSA, number of catheters, catheter types, and complications. SPSS 25.0 program (IBM SPSS statistics 25 software (Armonk, NY: IBM Corp.) was used for analyses. Mann Whitney U test was used to compare the ages of patients. The Spearman Chi-Square test evaluated the distribution among the categorical variables. A statistically significant value was taken as $p<0.05$.

Results

Our study included a total of 507 patients. Of these, 256 (50.5%) were male, and 251 (49.5%) were female. The mean age of patients was 49.2 years (range 5-91). The most preexisting comorbidity in patients diagnosed with DSA was hypertension (22.5%), followed by diabetes mellitus (8.1%). Demographic features and systemic disease of the patients are listed in Table 1.

Of the 507 patients, the most common indication for the diagnostic DSA procedure was subarachnoid hemorrhage (SAH) (21.7%), and to confirm and evaluate the aneurysms detected in magnetic resonance imaging (MRI) or computerized tomography angiography (CTA) (21.7%). In 15 patients, a Simmons 1 catheter (SIM 1); in 277 patients, a Simmons 2 catheter (SIM 2); in 329 patients, a vertebral catheter; and in 20 patients, a head-hunter catheter was used. Single catheters were used in 393 patients (77.5%), and more than one catheter was used in 114 patients (22.5%).

Table 1. Demographic data and comorbidities of the population

Demographic data		Number of patients with comorbidities	Rate of comorbidities in all patients (%)
Age		49.2±17.49	
Gender	**Male**	256	50.5
	Female	251	59.1
Diabetes Mellitus		41	8.1
Hypertension		114	22.5
Thyroid Dysfunction		16	3.2
Chronic Obstructive Pulmonary Disease		6	1.2
Cardiovascular Disease		22	4.3
Hypercholesterolemia		10	2.0
Malignity		11	2.2
Others		12	2.4

Procedural complications

Of 507 patients, a total of 10 patients had either a neurological complication, radiological complication, or angio-site-related complication, and the overall rate of complications was 0.02%. Complications were seen in five males and five females. The mean age of the patients who encountered complications was 48.90±9.06. Only 30% of the patients with complications have comorbidities, which are mostly hypertension (30%), and the SIM 2 catheter was used in 80% of the patients with complications.

In 6 patients, neurological complications occurred. Of those six patients, 3 (0.6%) had permanent neurological deficits, and 3 (0.6%) had transient deficits. One patient had aphasia, which was improved 2 hours later; one had generalized tonic-clonic seizure; and one had left hemiparesis, which was dissolved one week later. Permanent neurological deficits were caused by thromboembolism, and one patient with MCA thromboembolism died 21 days after the procedure.

In 4 patients with non-neurological complications, three were included in complications shown radiologically. Asymptomatic vasospasms were encountered in two cases, and vasospasms were resolved after nimotop injection. In one patient, internal carotid artery (ICA) dissection was encountered (Figure 1). However, the flow was not limited due to dissection. Aspirin was given to the patient, and no neurological symptom was seen. In one case, scrotal hematoma was observed after DSA, which was included in angio-site-related complications. One month later, it was observed that the hematoma had resolved. SIM 2 catheter was used in 80% of the patients with complications. Detailed information regarding the characteristics of the patients with complications is summarized in Table 2.

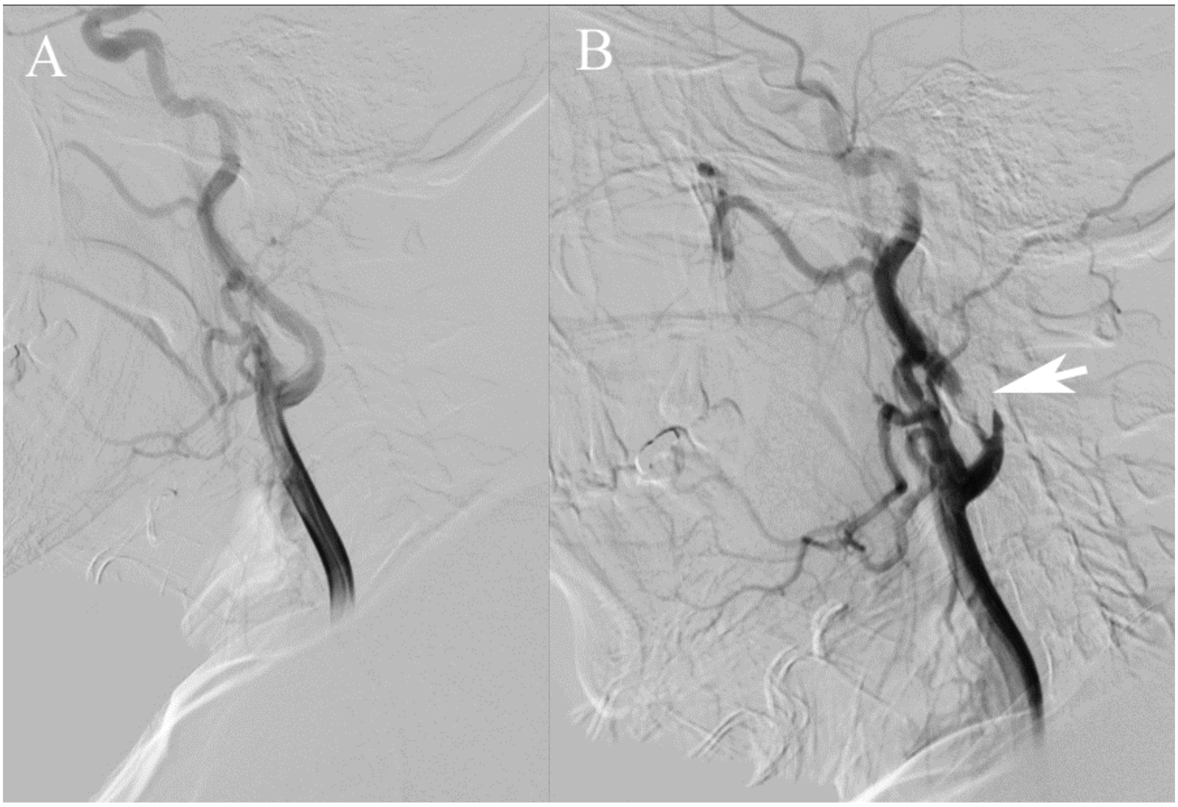

Figure 1. Following common carotid artery injection (A), internal carotid artery (ICA) was catheterized selectively. No pathology was detected following selective ICA injection, but a dissection in the cervical segment of ICA (B) was noticed during rotational imaging performed with the automatic injector. Since it did not cause any neurological deficit, no additional intervention was planned for the patient. The dissection site was indicated by an arrow

Table 2. Characteristics of patients with complications

Case No	Age	Gender	Comorbidity	Anesthesia	Indication	Catheter Type	No. Of Catheter Used	Complication	Type of Complication
1	63	F	HT	Sedation	ICH	Vertebral	1	MCA thromboembolism	Permanent
2	52	F	-	Local	Aneurysm on MRI or CTA	SIM1, SIM 2, vertebral	3	ICA posterior communication segment hromboembolism	Transient
3	54	M	HT	Local	ICH	Vertebral, SIM2	2	MCA thromboembolism	Permanent (exitus)
4	41	F	-	Local	SAH	SIM 2	1	GTC seizure	Transient
5	48	M	-	Local	ICH	SIM 2	1	Vasospasm	Radiological
6	53	M	-	Local	Aneurysm clip check	SIM 2	1	Scrotal hematoma	Transient
7	31	M	-	Local	ICA stenosis on MRI or CTA	SIM 2	1	Aphasia	Transient
8	57	M	-	Local	Stroke etiology	SIM2	1	MCA thromboembolism	Permanent
9	47	F	HT	Local	Aneurysm on MRI or CTA	SIM2, vertebral	2	ICA dissection	Radiological
10	43	F	-	Local	ICA stenosis detected on MRI or CTA	Vertebral	1	Vasospasm	Radiological

HT: Hypertension, MRI: Magnetic Resonance Image, CTA: Computerized Tomography Angiography, ICA: Internal Carotid Artery, MCA: Middle cerebral artery, GTC: Generalized Tonic-Clonic
SIM: The Simmons catheter, ICH: Intraparenchymal hematoma, SAH: Subarachnoid hemorrhage

Evaluation of the risk factors for complications

There were differences in the complication rates when they were analyzed for an association with age, anesthesia type, preexisting comorbidities, indication for DSA, and type of catheter used. The complication rate was similar in males (5 of 256, 1.96%) and females (5 of 251, 1.95%), and only hypertension was detected in patients with complications as preexisting morbidity. Gender (*p*=0.612), age (*p*=734), and comorbidities were not found to be statistically significant. The patients who underwent DSA to investigate the intracerebral hemorrhage (ICH) had the highest complication rate (9.1%), followed by the ICA stenosis detected on CTA or MRI (6.1%). ICH was associated with an increased risk in the DSA procedure (*p*=0.024). Although the P-value was insignificant for carotid stenosis (0.099), it can also be associated with an increased risk. Clinical indications for DSA and the rate of all complications are listed in Table 3.

In 5 patients with complications, only SIM2 catheters were used. In 3 patients, multiple catheters were used, including SIM2. In 2 patients, only vertebral catheters were used. Although the relationship of SIM2 catheters with complications is insignificant, its *p*-value is 0.093.

Table 3. Indications for DSA and rate of all complications and *P* values

Indication for DSA	Number of complications	Total number of angiograms for specified indication	Complication rate (%)	*p* value
ICH	3	33	9.1	0.024
SAH	1	110	0.91	0.324
Aneurysm on MRI-CTA	2	110	1.82	0.374
AVM on MRI-CTA	-	20	0	
Check after GKRS for AVM	-	18	0	
Check after the AVM operation	-	11	0	
Venous Angioma on MRI-CTA	-	17	0	
AVF on MR-CTA	-	4	0	
Vasculitis	-	3	0	
ICA dissection on MRI-CTA	-	10	0	
ICA stenosis on MRI or CTA	2	33	6.1	0.099
Check after Aneurysm clipping	1	32	3.1	0.482
Check after EVT	-	34	0	
Transient ischemic attack	1	27	3.7	0.424
Planning for GKRS	-	24	0	
Tumor Evaluation	-	5	0	
Others	-	16	0	
Total	10	507	1.97	

MRI: Magnetic Resonance Image, CTA: Computerized Tomography Angiography, AVM: Arteriovenous Malformation, AVF: Arteriovenous fistula
ICA: Internal Carotid Artery, EVT: Endovascular Treatment, GKRS: Gamma Knife Radiosurgery, DSA: Digital Subtraction Angiography
ICH: Intraparenchymal hematoma, SAH: Subarachnoid hemorrhage

Discussion

DSA is essential for diagnosing and evaluating intracranial vascular pathologies and tumors [18, 23]. Advancements in the catheter designs, contrast media, technical experience, and injection methods, complication rates continued to decrease [12, 24]. Although noninvasive imaging modalities such as MRI or CTA have reduced the use of DSA, these modalities had limitations as primary diagnostic tools in patients with SAH. Since the studies demonstrate that DSA can identify the lesion that causes SAH, in 4%-14% of patients with negative findings in CTA [6, 7] and the small vascular abnormalities cause intraparenchymal hematoma can be masked by the mass effect and hyperintensity of the hematoma [25], we performed diagnostic DSA for all patients with the suspected vascular pathologies which were detected on CTA or MRI.

In our series, the rate of neurologic complications associated with DSA was 1.2% (0.6% permanent; 0.6% transient). Our rate of permanent neurological disability is slightly higher than the other studies [12, 14, 19, 20]. This finding was expected as the numbers in this single-center experience need to be more significant to show similar results for the other studies and because of initial experiences in DSA. Dawkins et al. [15] show that ICH and SAH were associated with an increased risk of complications. In our study, the indication for DSA was ICH for the three patients with complications. Specific clinical and procedural factors are associated with an increased risk of complication. Studies define that patients with older age, coronary artery disease, peripheral arterial disease, or hypertension were also at high risk of complications during DSA procedures [19, 20, 26, 27]. Although the patient's age, gender, and comorbidities were not found significant, hypertension was the most common comorbidity, which was seen in our patients with complications.

Ischemic stroke and carotid stenosis were reported as risk factors in cerebral angiography [20, 26, 27]. Cloft et al. [28] defined that the neurological complication rate is higher for the patients investigated due to ischemic stroke compared to patients with SAH, aneurysm, or arteriovenous malformation (AVM). In our study, one patient with stroke etiology was evaluated with DSA, and MCA thromboembolism occurred as a complication with permanent neurological deficit. Besides being a risk factor, acute ischemic stroke is one the most severe complications that occur during DSA and is primarily caused by thromboembolism. It may be caused by multiple attempts to visualize stenotic vessels due to atherosclerotic plaque and plaque disruption by catheter or wire [12, 14, 26]. Also, a thrombus can form inside the catheters, or a hydrophilic coating can be formed over the catheter or wire [15, 29, 30]. Thromboembolism was the most devastating complication in our study-three permanent neurological deficits caused by thromboembolism.

Arterial dissections can also cause ischemic symptoms by limiting flow secondary to severe stenosis or occlusion or acting as a source of thromboembolism in DSA procedures. The intima layer of the vessel can be damaged by the manipulation of the catheter or the guidewire, and enlargement of the damaged intima can be seen because of injecting the contrast material under the intima [14, 23, 31]. Besides the interventionist's experience level, the catheter tip applying tension with cardiovascular pulsation against the arterial wall is important because it may damage the intima with the continuous pulsation [15, 31]. We encountered one carotid dissection during DSA procedure. In addition to catheter type, the number of catheters used for patients is important in evaluating the complications. Our study used more than one catheter in three patients with complications. Earnest et al. [13] found a higher correlation between neurological complications and the number of catheters used. Studies define that using smaller, softer catheters may decrease the risk of neurological complication rate [20, 32, 33]. Since only the SIM 2 catheter was used in 50% of our complicated patients, it was observed that this catheter type increased the risk of complications.

We realize that there were potential limitations in our study. Diffusion-weighted images (DWI) were not performed routinely after the DSA procedure. Therefore, subclinical events and silent thromboembolism were missed in our research and not counted as complications. However, subclinical events detected by DWI are much higher than expected, as shown in the studies [34-36]. Another limitation of the study is that the significance of risk factors could not be demonstrated statistically due to the small sample size. Furthermore, the data analysis and accuracy depended on our clinical follow-up and retrospective evaluations.

In conclusion, complications following DSA are rare but must be minimized with knowledge of the characteristics of the patients and determining the proper indication. Although the risk is low, complications such as thromboembolism can cause permanent neurological deficits and even death. As we know, using non-invasive imaging modalities has decreased the use of DSA, endovascular treatments, and therapeutic catheter-based procedures continuously increasing. In our initial 3-year experience in DSA, we found a 1.2% rate of complications leading to neurological deficits (0.6% permanent; 0.6% transient).

Conflict of interest: No conflict of interest was declared by the authors.

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Authors’ contributions to the article

S.C. and F.Y. have constructed the main idea and hypothesis of the study. S.C. and B.B.B. developed the theory and arranged/edited the material and method section. S.C., E.T. and M.E.C. have done the evaluation of the data in the results section. Discussion section of the article was written by S.C., F.Y., E.T. and M.E.C. reviewed, corrected and approved. In addition, all authors discussed the entire study and approved the final version.