Original Paper

Safety of Diagnostic Cerebral and Spinal Digital Subtraction Angiography in a Developing Country: A Single-Center Experience

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Digital subtraction angiography · Interventional neurology · Neuroendovascular surgery · Spinal angiography · Pediatric angiography

Abstract

Background: Digital subtraction angiography (DSA) remains the gold standard imaging modality for cerebrovascular disorders. In contrast to developed countries, the safety of the procedure is not extensively reported from the developing countries. Herein, we present a retrospective analysis of the basic technique, indications, and outcomes in 286 patients undergoing diagnostic cerebral and spinal angiography in a developing country, Pakistan. **Methods:** A retrospective review of patient demographics, procedural technique and complication rates of 286 consecutive patients undergoing the diagnostic cerebral/spinal angiography procedure at one institution from May 2013 to December 2015 was performed. Neurological, systemic, or local complications occurring within and after 24 h of the procedure were recorded. **Results:** Mean age reported for all patients was 49.7 years. Of all the 286 cases, 175 were male (61.2%) and the rest female (111, 38.8%). Cerebral DSA was performed in 279 cases (97.6%), with 7 cases of spinal DSA (2.4%). Subarachnoid hemorrhage was the most common indication for DSA accounting for 88 cases (30.8%), closely followed by stroke (26.6%) and arteriosclerotic vascular disease (23.1%). No intra- or post-procedural neurological complications of any severity were seen in any of the 286 cases. One case of asymptomatic aortic dissection was reported (0.3%) in the entire cohort of patient population. **Conclusion:** Diagnostic cerebral/spinal digital subtraction angiography was found to be safe in Pakistan, with complication rates at par with and comparable to those reported in the developed world.

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Background

Noninvasive vascular imaging like duplex ultrasound, computed tomographic angiography and magnetic resonance angiography have replaced the routine indications for diagnostic cerebral/spinal angiography (DSA) [1–3]. While both invasive and noninvasive vascular imaging and reporting standards are strictly enforced through cognitive and technical training in the western world [4], this is not the norm in developing countries. Additionally, a lack of uniform health insurance system promotes a biased private healthcare system which puts excessive financial burden on the patient if successive noninvasive imaging modalities are performed with no definitive diagnosis or even misdiagnosis.

DSA can be performed for entirely diagnostic purposes or with an “intent to treat” purpose in most cases. Operator training and experience in catheter techniques, disease pathology, and extra/intracranial vascular anatomy along with preprocedural evaluation and post-procedural management are key factors to a successful procedural outcome. Digital subtraction cerebral angiography has the advantage of looking at all three blood flow phases, i.e. arterial, capillary, and venous [5] and hence maintains a standardized pattern.

In the health-care environment as described above, for patients with nontraumatic subarachnoid hemorrhage undergoing CT angiography, MR angiography, or digital subtraction cerebral angiography, DSA offers higher efficacy, superiority, and quality-adjusted life-years, as reported in a recent European study [6]. In the case of arteriovenous malformations, while both CT and MRI are able to show the malformation, DSA remains a preferred choice for studying the detailed angiographic architecture [7]. Advancements in catheter-based techniques and technology along with operator experience have drastically reduced the complication rate associated with this invasive imaging modality [8–10].

Materials and Methods

A retrospective analysis of patient data forms of 286 consecutive cerebral and spinal angiography examinations done at our medical center by a single operator (Q.B.) from May 2013 to December 2015 was performed. Therapeutic interventional procedures were excluded. All patients referred for angiography were first examined and screened for procedural appropriateness.

Indications and Contraindications

Indications for DSA were broadly divided into cerebral and spinal diseases. Cerebral indications are further classified based on intracranial and extracranial pathology. Table 1 enlists these indications in detail. Although there are no absolute contraindications to the angiography procedure, some relative contraindications were considered. These included renal insufficiency, any history of a severe anaphylactic reaction to the contrast medium (even with steroid pretreatment) or a coagulopathy with an increased risk of delayed hemostasis.

Preprocedure

Preprocedure assessment included review of pertinent hematological lab data and neuroimaging data. A comprehensive neurological examination was performed by the operator and written informed consent was obtained. Oral anticoagulants were discontinued prior to the procedure.

Procedure

As per our institutional practice guidelines, a radiology nurse administered moderate conscious sedation to patients requiring it. Only the spinal angiography procedures were performed under general anesthesia provided by the hospital anesthesia service.

All procedures were performed on a single-plane DSA machine. The angiographic technique remained relatively unchanged except for periodic updates in guide catheters and guide wires. All patients, except 1, underwent common femoral artery access using a 5-Fr sheath set to a continuous heparinized saline infusion.

Table 1. Neuroangiography indications

Extracranial	Intracranial	Spinal
Carotid stenosis	Acute stroke	Dural arteriovenous fistula
Carotid blowout	Intracranial atherosclerotic disease/stenosis	Spinal arteriovenous malformation
Carotid dissection/pseudoaneurysm	CNS vasculopathy/vasculitis	
Vertebral artery stenosis	Nontraumatic subarachnoid hemorrhage	
Subclavian steal	Cerebral aneurysm	
Uncontrolled epistaxis	Cerebral arteriovenous malformation	
Preoperative tumor embolization	Cerebral arteriovenous fistula	
Carotid cavernous fistula	Cerebral vasospasm	
Cerebral sinus/vein occlusion		
Carotid cavernous aneurysm	Preoperative tumor embolization	
Bowhunter syndrome	WADA test	
Balloon occlusion test		

The main guide catheters used were 5-Fr Weinberg, Simmons II, Vertebral, Cerebral, JR4, and Pigtail (only for Arch Aortography). Standard spinal angiography catheters used at our institution were 5-Fr Mikaelsson and Cobra. For preventing air embolism, we used in-line air filters and a closed angiographic system (Carefusion Alaris™, USA) in which heparinized saline flush (2,000 IU/L) was administered through the guide catheter continuously and contrast injection facilitated through the use of a stopcock.

Postprocedure

Hemostasis was obtained through manual compression for 15–20 min. Patients were monitored by a nurse in the recovery area during strict bed rest for at least 4 h. All patients underwent a neurological and peripheral vascular examination at the time of discharge performed by the interventional neurology team.

Data Analysis

Detailed procedural reports of all patients from May 2013 until December 2015 were retrospectively reviewed. Patient reports included patient data as listed in Tables 1 and 2 below.

Results

The mean age of the patients was 49.7 years (Table 3). Out of a total of 286 patients, 175 were male (61.2%, mean age 52 years) and 111 were female (38.8%, mean age 52 years). A subpopulation of 16 pediatric patients was identified as those younger than 21 years of age (5.6%, mean age 14.5 years, 11 males). The three most common angiographic indications

Table 2. Patient data reviewed

Category	Information
Patient data	Name Age, years Gender
Indication/s	Atherosclerotic disease Stroke TIA Headaches Seizures Aneurysms Arteriovenous malformation Intracerebral hemorrhage Subarachnoid hemorrhage Dural arteriovenous fistula Vasculitis Tumor Moyamoya Dissection
Angiographic approach	Retrograde femoral Retrograde brachial/radial Direct carotid
Number of catheters used	1 or >1
Vessels catheterized	Aortic arch Right or left common carotid Right or left internal carotid Right or left external carotid Right or left vertebral artery Right or left subclavian artery Thoracic intercostal arteries Lumbar spinal arteries Thyrocervical
<i>Complications</i>	
(a) Local	Hematoma (any size) Infection Thrombosis
(b) Systemic	Nausea, vomiting Hypotension Chest pain, arrhythmia Anaphylaxis, hemodynamic collapse Acute renal failure Death
(c) Neurological	Stroke Blindness
Transient, <24 h	Aphasia
Reversible, >24 h and <7 days	Seizure
Permanent, >7 days and fixed	Other

Table 3. Baseline data of patients examined between April 2013 and December 2015

Total, <i>n</i>	286
Pediatrics (<21 years)	16 (5.6%)
Spinal	7 (2.4%)
Mean patient age, years	49.7
Males	175 (61.2%)
Females	111 (38.8%)
<i>Indication (total 286 patients)</i>	
SAH	88 (30.8%)
Stroke	76 (26.6%)
ASVD	66 (23.1%)
TIA	29 (10.1%)
ICH	29 (10.1%)
Aneurysm	26 (9.1%)
DAVF	19 (6.6%)
AVM	16 (5.6%)
Headaches/CN palsy/tinnitus	12 (4.2%)
New-onset seizures	5 (1.7%)
Tumor	2 (0.7%)
Moyamoya	2 (0.7%)
<i>Angiographic approach</i>	
Femoral	285 (99.7%)
Radial	1 (0.3%)
Number of catheters used	331; mean 1.16
1	299 (90.3%)
>1	32 (9.7%)
<i>Vessels catheterized (total 286 patients)</i>	
Aortic arch	4
Right CCA	111
Left CCA	122
Right subclavian artery	59
Left subclavian artery	50
Right internal carotid artery	128
Left internal carotid artery	126
Right external carotid artery	37
Left external carotid artery	25
Right vertebral artery	65
Left vertebral artery	131
Complete spinal (thyrocervical, thoracic, and lumbar spinal arteries)	7

(Fig. 1–3) were subarachnoid hemorrhage accounting for 88 cases (30.8%), followed by 76 cases of stroke (26.6%) and 66 instances of arteriosclerotic vascular disease (23.1%). A subpopulation of patients (81, 30.8%) having more than one indication for angiography was identified. This included patients with any number of combinations of 2 or more diseases which accounted for their ailment and hence served as indications for the procedure.

Amongst the pediatric population, the most common indication for angiography was intracerebral hemorrhage (6, 37.5%). Out of the 16 pediatric patients, cerebral angiography was performed on 14 (87.5%), while 2 underwent spinal procedure.

Fig. 1. A 44-year-old man with no pertinent past medical history presented with a 1.5-month history of recurrent attacks of complete right vision loss (amaurosis fugax). Noninvasive imaging including carotid Doppler, brain CT + MRI and brain computed tomographic angiography were reportedly normal. His hematological workup revealed ESR 30, WBC 12, mildly deranged LFTs and thrombocytopenia. **a** Right ICA angiography (lateral projection) at 1.67 s. Note, right ophthalmic artery subtle irregularity and delayed antegrade flow compared to the normal left ophthalmic artery (**b**). **b** Compared to the right ophthalmic artery, note brisk antegrade filling and smooth caliber of the normal left ophthalmic artery at 1.67 s.

Fig. 2. A 4-year-old male child with spontaneous left parieto-occipital intracerebral hemorrhage. Note left posterior cerebral artery branch fed arteriovenous fistula.

Fig. 3. **a** Stenosis of the right common carotid artery is seen. **b** Delayed right hemisphere filling secondary to proximal stenosis.

Of all the procedures, cerebral angiography was performed in 279 cases (97.6%), whereas spinal procedure accounted for 7 cases (2.4%). A single catheter was used in 90.3% of procedures. Retrograde femoral artery approach was used to perform the procedure in 99.7% of cases, with only 1 case (0.3%) requiring radial artery access.

Complications

Intraprocedural Complications

Intraprocedural complications were divided into local, systemic, and neurological. No local or systemic complications were seen. No neurological complications, classified as transient (<24 h), reversible (24 h to 7 days), or permanent (>7 days) were reported. One asymptomatic procedural complication (0.3%) of descending aortic dissection was reported in our entire cohort of patient population. No complications were seen in the pediatric population. Also there were no complications in any of the spinal angiography procedures.

Postprocedural Complications

No postprocedural complications were seen during the recovery period; particularly, there were no episodes of stroke or seizure; no focal neurological deficits (blindness/aphasias), either after the procedure or at the time of discharge, were seen. There were no instances of anaphylaxis to contrast medium, nephrotoxicity secondary to the use of contrast medium, nausea, vomiting, or systemic hemodynamic collapse.

Discussion

This retrospective analysis of DSA at a single center in Pakistan reveals complication rates well within the range as specified in the cooperative statement issued by the Society of Interventional and Therapeutic Neuroradiology and American Academy of Neuroradiology [11]. According to these guidelines, the allowable complication rate threshold for reversible neurological deficits is 0–2.5% and for permanent neurological deficits up to 1%. Our complication rate of 0% for all neurological deficits is comparable to both, the reported and the suggested rates [11].

Our complication rates are also similar to those reported by other researchers who have reported 0% neurological complications [12]. In their study, a total of 1,715 consecutive diagnostic cerebral angiographies were performed at a single center, and a complication rate of 0% was reported for any stroke or permanent neurological deficit. The incidence of asymptomatic aortic dissection was reported in 4 cases (0.2%), which is comparable to the 1 case (0.3%) reported in our study. This single incidence of aortic dissection did not require additional hospital stay or stenting and was completely asymptomatic. The patient, a 50-year-old female, had suffered a prior subarachnoid hemorrhage for which an angiography procedure was performed sometime earlier at another institution. In consideration to this, radial artery access was used to perform the procedure. It is worth mentioning that this was the only case in the entire cohort in which radial artery approach was used. These results are also comparable to those reported by Johnston et al. [13] in a study conducted on 569 patients with a number of comorbidities, both symptomatic and asymptomatic. This study reported an overall complication rate of 0.9%, of which stroke accounted for 0.5% and TIA for 0.4%. No arterial dissections (0%) were reported during this study. In order to account for the difference in complication rates reported in our study and those by Johnston et al. [13], one possible reason could be the use of heparinized flush system in all the procedures performed at our institution, with no such mention in the latter. Another large scale study conducted by Dawkins et al. [14] prospectively analyzed data from 2,924 consecutive cerebral angiogra-

phies and reported neurological complications in only 0.34% of cases with no permanent neurological event occurring in the entire cohort. One of the largest studies investigating the safety and complications following cerebral angiography was conducted in 2007 by Kaufmann et al. [15]. In this study, data for 19,826 cerebral angiographies from 1981 to 2003 were retrospectively reviewed and an overall neurological complication rate of 2.63% was reported with 0.14% of cases suffering permanent neurological deficit. Our complication rates, when compared with both large- and small-scale studies, not only corroborate but extend the findings reported in these. Of the 81 patients (30.8%) who had more than one indication for angiography, none contributed to the complication rates, signifying that the number of indications or ailments of the patient has little to no role in the outcomes of the procedure. This goes to show that the use of DSA could potentially be advocated for both symptomatic and asymptomatic patients, with or without comorbidities.

In all of the 7 cases where spinal digital subtraction angiography (SpDSA) was performed, no neurological or nonneurological complications were seen. Although the number of studies investigating complications in exclusively spinal angiographies is low, rates similar to ours have been reported in those studies [16, 17]. The complication rate for SpDSA has drastically declined from 2.2% [18] for neurological deficits reported in 1988 to effectively 0%, as reported in some of the recent studies. A study conducted by Kieffer et al. [16], over a period of 15 years from 1985 to 2000, assessed 487 SpDSA cases that were performed as an adjunct to aortic aneurysmectomy and revealed an overall complication rate of 1.2% for major-procedure related events and 0.8% for any neurological deficit (0.6% permanent). In 2011, another 10-year retrospective single center study by Chen et al. [17] reported no intra- or postprocedural neurological complications in the entire cohort during which 302 consecutive diagnostic spinal angiographies were performed. Our complication rate of 0% is either lower than, or comparable to the studies mentioned earlier.

With the increase in understanding and recognition of cerebrovascular disorders in the pediatric population, there has been a concomitant rise in the number of studies exploring the safety and efficacy of angiography in this population. These cases have been considered separately in our study due to the unique anatomy and physiology of pediatric cerebral vasculature, increased vessel fragility and smaller caliber, all of which makes these cases more susceptible to complications secondary to catheter-based angiography. The complication rate of 0% seen in the pediatric population is consistent with a number of studies [19–21]. In a study conducted by Burger et al. [19], data from an exclusively pediatric population of 241 cases were retrospectively analyzed, and complication rates of 0 and 0.4% were reported for intra- and postprocedural events, respectively [15]. Recently, another study conducted by Ning et al. [20] analyzed data from 429 consecutive diagnostic angiograms performed on children younger than 18 years of age and reported a complication rate of 0% for any neurological event and 0.7% for nonneurological events (2 intraprocedural and 1 postprocedural). Similar results were reported by Hoffman et al. [22] in a study where 309 cerebral angiograms were obtained from 87 children younger than 3 years of age. The rate of neurological complications in this study was 0% and for nonneurological complications 2.9%. These results help encourage the use of DSA safely in all age groups with complication rates similar to those reported in adult populations.

Both angiography equipment and operator skills have led to a significant reduction in neurological complications over the recent years. Use of continuous catheter flush systems employing heparinized saline that is infused via dedicated pumps with air embolism protection systems has further lowered the complication rates.

Conclusion

In a developing country like Pakistan, conventional cerebral angiography (DSA) is a cost-effective and safe method for providing detailed information on the cerebrovascular anatomy and adding to patient-specific treatment plan.

Statement of Ethics

Protocols for obtaining Ethics Certificate from the respective institutions were fulfilled along with acceptance of full responsibility and compliance to maintaining patient confidentiality.

Disclosure Statement

The authors report that there is no conflict of interest to disclose. The authors do not have any personal, professional or otherwise affiliations with any product mentioned in the text. This research paper received no funding from any official/nonofficial source, whatsoever.

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