The Egyptian Journal of Hospital Medicine (October 2018) Vol. 73 (9), Page 7448-7453

Evaluation of Diagnostic Cerebral Angiography at Al-Hussein Neuro-Intervention Unit

Sayed Ahmed Fathy El-Zayat[1], Mohamed Fouad Abd El-Moaty[2], Khaled Mohamed Sobh[1], Hamada Abd-Eltwab Salama Mohamed[1*]

Departments of Neurology[1] and Radiology[2], Faculty of Medicine, Al-Azhar University

***Corresponding author:** Hamada Abd-Eltwab Salama Mohamed, **E-mail:** alaamash3al@gmail.com

ABSTRACT

Background: digital subtraction angiography (DSA) is important diagnostic tool for evaluation of cerebral vasculature and provides essential information regarding hemodynamic status and collateral circulation in patients with stroke and vascular malformations, so it is ideal imaging method of choice for diagnosis of cerebrovascular diseases.

Aim of the Work: to register all cases undergoing diagnostic cerebral angiography in Al-Hussein University hospital, neuro-intervention unit performed by a neuro-interventional team and evaluate the results, and outcome of this procedure.

Materials and Methods: the present study is single-center study included all patients subjected to diagnostic cerebral angiography during period from 2006 to 2018. The study protocol was approved by the local Ethics Committee in Al-Azhar University. The patients had been recruited from Al-Hussein and Sayed Galal Hospital outpatient's clinics, internal departments and stroke units, which indicated for diagnostic cerebral angiography.

Results: in the present study the mean age of patients with arterial stenosis was (55.47 ±8.80), 1049(51%) of them were males, 1009(49%) were females. In our study, mild stenosis was present in 254 (12.3%), moderate stenosis in 525 (25.5%), severe stenosis in 567 (27.6 %), subtotal occlusion in 315 (15.3%) and total occlusion in 397 (19.3%) of the patients which detected by DSA.

Conclusion: arterial stenosis is more common than cerebral aneurysms and AVM in the patients who subjected to DSA. The presence of hypertension and diabetes mellitus were found to be significantly more prevalent among patients with arterial stenosis. However, the prevalence of hypertension and smoking were more prevalent in cerebral aneurysms.

Keywords: Diagnostic Cerebral Angiography, Doppler ultrasonography.

INTRODUCTION

Digital subtraction angiography (DSA) is important diagnostic tool for the evaluation of cerebral vasculatures and provides essential information regarding hemodynamic status and collateral circulation in patients with stroke. It is an ideal imaging method of choice for diagnosis of cerebrovascular disorders [(1)].

DSA is important in spontaneous intracranial haemorrhage if surgery is indicated, and to find the aetiology of the bleeding, particularly if intracranial aneurysm and arteriovenous malformation (AVM) are present, in which surgical or endovascular intervention significantly reduce the re-bleeding risk [(2)].

Noninvasive imaging such as Doppler ultrasonography CTA and MRA, have gained increasing importance in the diagnosis of cerebrovascular disease, and in many circumstances, the accuracy of noninvasive angiographic data may be sufficient to supplement catheter angiography [(3)].

However, DSA remains the gold standard for evaluating the cerebral vessels with regard to determining the degree of arterial stenosis and the presence of dissection, vasculopathy, vasculitis or occult lesion such as vascular malformation and provides information about collateral circulation and perfusion [(4)].

In addition catheter angiography is frequently reserved for cases in which noninvasive imaging results are not diagnostic or consistent [(5)].

DSA has been preferred follow up imaging modality for detecting in-stent re-stenosis after intracranial stenting [(6)].

Although, less invasive techniques for follow up investigations would be described (particularly in patient at high risk for instent restenosis), non invasive imaging as TCD, CTA, MRA is potentially affected by artifact and hemodynamic changes [(6)]. DSA has a risk of peri and post procedural complications (e.g., embolism, dissection, retroperitoneal hematoma, allergic reaction to contrast medium, nephropathy), particularly in older patient with polyvascular atherosclerosis, resulting in a morbidity and mortality from 1 to 4 % [(7)].

AIM OF THE WORK

To register all cases undergoing diagnostic cerebral angiography in Al-Hussein University hospital, neuro-intervention unit performed by a neuro-interventional team and evaluate the results, and outcome of this procedure.

Received:4/9/2018
Accepted:23/9/2018

MATERIALS AND METHODS

The present study is single-center study; included all patients subjected to diagnostic cerebral angiography during period from 2006 to 2018. The study protocol was approved by the local Ethics Committee in Al-Azhar University.

The patients had been recruited from Al-Hussein and Sayed Galal Hospital outpatient's clinics, internal departments and stroke units, which indicated for diagnostic cerebral angiography with the following inclusion and exclusion criteria:

Inclusion criteria:

All patients were subjected to diagnostic cerebral angiography at Al-Hussein neuro-intervention unit e.g. (patient with carotid stenosis, intracranial stenosis, AVM and SAH) at any age and sex.

Exclusion criteria

Patient with:

- Elevated serum creatinine
- Patients have history of allergy
- Patients who's refuse to do the procedure

Methods

All the patients' undergo the following:

Full medical and neurological history.

Neurological examination at two points before and immediately after the procedure.

Assessment of vascular anatomy e.g. (duplex and MRA in a patients with stroke and CTA in a patients with AVM and SAH).

Procedure:

1. All patients selected for Diagnostic Cerebral Angiography had done with local anesthesia in the femoral puncture site or axillary area in brachial approach and appropriate cardiac monitoring, general anesthesia for patients who could not follow commands.
2. Puncture is done using an 18-gauge puncture needle. A 5F sheath (Check-Flo® Performer® Introducer set; Cook, Bloomington, IN) is slowly and continuously perfused with heparinized saline (10,000 U heparin per liter of saline) under arterial pressure and a 0.035" J-tipped hydrophilic guide wire with puncture and wire is inserted (Seldinger technique)
3. During the initial placement of the diagnostic catheter in the aortic arch, use a 0.035 hydrophilic wire to advance the diagnostic catheter into the vessels. The used catheter is 5 French diagnostic catheters (Vertebral or Simmon II catheter -Boston Scientific or Cordis).
4. Diagnostic cerebral angiography consists of visualization of both common carotid arteries including the external carotid artery, the internal carotid artery, the carotid bulb, the siphon, the extra cranial part, the intra cranial part and the T-carotid in several projections, Also it includes both vertebral arteries and the basilar artery. Finally, the state of collaterals and the presence of any physiological or pathological anastomosis.
5. Several projections should be considered such as the AP, Lateral, Oblique and Towne views according to each case to visualize any pathology accurately.
6. Catheter Sheath removal and puncture site hemostasis.

Statistical analysis

The data collected were tabulated and analyzed by using SPSS (statistical package for the social science software). Quantitative data were expressed as mean and standard deviation (x± SD) and analyzed by applying t-test for comparison of two groups of qualitative data were expressed as numbers and percentage (No & %) and analyzed by applying chi-square (x2) test. All these were used as tests of significance at p 0.05.

RESULTS

Table (1): Comparison between results of stenosis on DSA and on CTA

	Percentage of stenosis on DSA	Percentage of stenosis on CTA	Test value	P-value	Sig.
Median (IQR) Range	70 (50 – 90) 0 – 100	65 (0 – 90) 0 – 100	-11.478#	0.000	HS
Mild stenosis	190 (15.1%)	294 (23.3%)	27.659	0.000	HS
Moderate stenosis	252 (20.0%)	254 (20.2%)	0.010	0.920	NS
Severe stenosis	357 (28.3%)	294 (23.3%)	8.220	0.004	HS
Subtotal occlusion	210 (16.7%)	209 (16.6%)	0.003	0.956	NS
Total occlusion	251 (19.9%)	209 (16.6%)	4.691	0.030	S

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant

*: Chi-square test; #: Wilcoxon Signed Ranks Test

Table (1) shows comparison between results of stenosis on DSA and on CTA, we find highly significant difference in mild and severe stenosis results, non significant difference in moderate stenosis and subtotal occlusion results and significant difference in total occlusion between CTA, DSA.

Table (2): Comparison between results of duplex and DSA in arterial stenosis

	Percentage of stenosis	Percentage of duplex	Test value	P-value	Sig.
Median (IQR) Range	70 (50 – 90) 0 – 100	0 (0 – 50) 0 – 90	-28.076#	0.000	HS
Mild stenosis	169 (11.5%)	529 (36.0%)	243.479	0.000	HS
Moderate stenosis	419 (28.5%)	449 (30.5%)	1.471	0.225	NS
Severe stenosis	441 (30.0%)	276 (18.8%)	50.218	0.000	HS
Subtotal occlusion	231 (15.7%)	126 (8.6%)	35.151	0.000	HS
Total occlusion	210 (14.3%)	90 (6.1%)	53.455	0.000	HS

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant
*: Chi-square test; #: Wilcoxon Signed Ranks Test

Table (2) shows comparison between results of duplex and DSA in arterial stenosis, we find highly significant difference in all degree of stenosis except moderate stenosis which is non-significant.

Table (3): Comparison between results of DSA, MRA

	Percentage of stenosis	Percentage of MRA	Test value	P-value	Sig.
Median (IQR) Range	70 (50 – 90) 0 – 100	65 (0 – 85) 0 – 100	-7.104#	0.000	HS
Mild stenosis	126 (13.6%)	315 (34.1%)	106.388	0.000	HS
Moderate stenosis	273 (29.5%)	143 (15.5%)	34.353	0.000	HS
Severe stenosis	315 (34.1%)	235 (25.4%)	16.567	0.000	HS
Subtotal occlusion	126 (13.6%)	127 (13.7%)	0.005	0.944	NS
Total occlusion	84 (9.1%)	104 (11.3%)	2.369	0.124	NS

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant
*: Chi-square test; #: Wilcoxon Signed Ranks Test

The table show comparison between results of DSA, MRA, we find highly significant difference in mild, moderate, severe stenosis and non significant difference in subtotal and total occlusion.

Table (4): Comparison between the results which detected by DSA and CTA in cerebral aneurysms

	Result of DSA No. = 557		Result of CTA No. = 557		Test value*	P-value	Sig.
Normal	115	20.6%	283	50.8%	110.334	0.000	HS
P.com aneurysm	143	25.7%	95	17.1%	12.311	0.000	HS
A.com aneurysm	141	25.3%	126	22.6%	1.108	0.293	NS
PICA aneurysm	12	2.2%	0	0.0%	12.131	0.000	HS
PCA aneurysm	5	0.9%	0	0.0%	5.023	0.025	S
ACA aneurysm	6	1.1%	0	0.0%	6.032	0.014	S
SCA aneurysm	6	1.1%	0	0.0%	6.032	0.014	S
MCA aneurysm	23	4.1%	10	1.8%	5.278	0.022	S
ICA aneurysm	22	3.9%	5	0.9%	10.970	0.001	HS
Basilar aneurysm	55	9.9%	38	6.8%	3.391	0.066	NS
Multiple aneurysms	23	4.1%	0	0.0%	23.485	0.000	HS
Paraophthalmic aneurysm	6	1.1%	0	0.0%	6.032	0.014	S

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value< 0.01: highly significant (HS)
*:Chi-square test

The table show comparison between the results which detected by DSA and CTA, we find highly significant difference in normal results, P.com aneurysm, PICA aneurysm, ICA aneurysms, multiple aneurysms and non significant difference in A.com aneurysm, baila aneurysm and significant difference in PCA aneuysms, aca aneurysm, SCA aneurysm, MCA aneurysm and paraophthalmic aneurysm.

Table (5): Comparison between results of DSA and MRA in patients with cerebral aneurysms

	Result		MRA		Test value*	P-value	Sig.
	No. = 557		No. = 557				
Normal	115	20.6%	486	87.3%	497.326	0.000	HS
P.com aneurysm	143	25.7%	12	2.2%	128.611	0.000	HS
A.com aneurysm	141	25.3%	6	1.1%	142.827	0.000	HS
PICA aneurysm	12	2.2%	0	0.0%	12.131	0.000	HS
PCA aneurysm	5	0.9%	0	0.0%	5.023	0.025	S
ACA aneurysm	6	1.1%	6	1.1%	0.000	1.000	NS
SCA aneurysm	6	1.1%	0	0.0%	6.032	0.014	S
MCA aneurysm	23	4.1%	17	3.1%	0.934	0.338	NS
ICA aneurysm	22	3.9%	12	2.2%	3.034	0.082	NS
Basilar aneurysm	55	9.9%	6	1.1%	41.641	0.000	HS
Multiple aneurysms	23	4.1%	12	2.2%	3.569	0.059	NS
Paraophthalmic aneurysm	6	1.1%	0	0.0%	6.032	0.014	S

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value< 0.01: highly significant (HS)
*:Chi-square test

The table show comparison between results of DSA and MRA in patients with intracranial aneurysms, we find highly significant difference in normal result, PCOM, A.Com, PICA and basilar aneurysms while non significant difference were present in ACA, MCA, ICA, multiple aneurysms and significant difference present in PCA, SCA, paraoptheluic aneurysms.

Table (6): Comparison between results of CTA and DSA in the patients with AVM

	Result		CTA		Test value*	P-value	Sig.
	No. = 557		No. = 557				
Normal	17	3.9%	169	38.9%	157.993	0.000	HS
Ant.circulation AVM	321	73.8%	212	48.7%	57.546	0.000	HS
Posterior circulation AVM	79	18.2%	41	9.5%	10.116	0.001	HS
Carotid cavernous Fistula	13	3.0%	13	3.0%	0.000	1.000	NS
Vein of gallen malformations	5	1.1%	0	0.0%	5.029	0.025	S

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value< 0.01: highly significant (HS)
*:Chi-square test

DISCUSSION

Diagnostic Cerebral catheter angiography (DSA)-based study was conducted, being minimally-invasive in nature, fast and sensitive and with very high sensitivity index [(4)].

We focused on stenotic lesions, intracranial aneurysms and AVM and then evaluated the results, outcome and complications in those patients who subjected to DSA and compared the results with similar studies in other countries.

We evaluated sites, results, complications and associated medical conditions in the patients with arterial stenosis whose subjected to DSA and compare these results with results of pre catheterization images to detect it is accuracy.

We considered a stenosis either mild, moderate, severe, subtotal or total occlusion according to its degree:

(1) Less than 50 %: mild stenosis
(2) 50-70 %: moderate stenosis
(3) 70-90 %: severe stenosis
(4) 90 -99 %: subtotal occlusion
(5) 100 %: total occlusion

Also, we evaluate sites, results, outcome, complications and associated medical conditions in both intracranial aneurysms and AVM and compare these results with results of pre-catheterization images to detect it is accuracy.

We used Catheter cerebral angiography as the modality for investigation as it is the gold standard. Magnetic resonance angiography (MRA) and duplex ultrasound are some non-invasive alternatives but limitations of MRA include motion artifacts, long examination time, loss of signal due to turbulence and in-plane saturation leading to exaggeration of stenosis, poor demonstration of calcium and bony landmarks, and limitations in evaluating postoperative patients with metallic clips and stents. Duplex is operator-dependent and limited in evaluating the intracranial vasculature [(4)].

Unlike ultrasonography or MRA, CTA provides direct imaging of the arterial lumen suitable for evaluation of stenosis, aneurysms and AVM. CTA is less susceptible than MRA to overestimating the severity of cerebral vessel stenosis, inability to detect small aneurysms or AVM. CTA is extremely fast, less expensive than contrast-enhanced MRA, provides a faster processing time, and can visualize soft tissue, bone, and blood vessels at the same time but CTA is limited in its ability to provide physiological data, such as flow velocity or direction. Also, CT angiographic imaging of the cerebral circulation is associated with a number of known artifacts **[(6)]**.

In the present study the mean age of patients with arterial stenosis was (55.47 ±8.80), 1049(51%) of them were males, 1009(49%) were females.

While it was 1355 male (46%), and 1569 female (54%) in study done by ***Dawkins et al.*** **[(8)],** with mean age was 45.4 years.

There were angiographic findings in 1848 (88.8 %) patients, while the other 210 (10.2 %) had normal course and caliber of cerebral arteries ischemic stroke 1974 was the most frequent presentation(95.9) followed by TIAS in 84 (4.1), while subarachnoid hemorrhage was the most common presentation in the study done by ***Lehmann et al.*** **[(9)].**

Hypertension, diabetes mellitus, smoking, cardiac diseases and family history were risk factors; Hypertension was most significantly associated with significant stenosis, present in 1513 (73.5 %) patients, followed by diabetes mellitus in 1302 (63.3 %) patient.

That was controversy to ***Dawkins et al.*** **[(8)]*;* *Sacco et al.*** **[(10)]** who present smoking as the most significant association followed by hypertension, this due to low incidence of smoking in Egyptian females which constitute 49% of our patient.

In our study, mild stenosis was present in **254 (12.3%),** moderate stenosis in **525 (25.5%)**, severe stenosis in **567 (27.6 %),** subtotal occlusion in **315 (15.3%)** and total occlusion in **397 (19.3%)** of the patients which detected by DSA.

We were find complications in (0.58%) of the patients while it was like (1.2%) in study conducted by ***Dawkins et al.*** **[(8)]**, in our study the complications classified into 5 (0.24%) with groin hematoma, 4 (0.19%) with transient neurological deficit, 3 (0.15%) with arterial dissection, while in the study by **Dawkins**, most common complication was **groin hematoma (12%)** followed by **Transient neurologic deficit** and **carotid or vertebral artery dissections (10%).**

As regard findings, mean age for intra-cranial aneurysms was (42.63± 9.32), 243 (43.6 %) for females and 314 (56.4 %) for males, similar to study done by ***Dawkins et al.*** **[(8)]** where mean age was 45.4 years (SD 15 years); 1355 were male (46%), 1569 were female (54%), While in study by ***Badr et al.*** **[(11)]** (32%) 10 females and (68%) 19 males came with different ages from 3rd to 7th decade, which mean that the aneurysm develops in all ages and the majority in adult between 30 to 60 years, the study was conducted only on 29 patients.

Hypertension, diabetes mellitus, smoking, collagen diseases and family history were risk factors, **Hypertension** was most significantly associated with intracranial aneurysms, present in 250 (44.9%) patients, followed by smoking in 244 (43.8 %) patient then diabetes mellitus in 113 (20.3%) while positive family history and collagen disorders present in around (5 %) this agree with the study conducted in 2007 by ***Lehmann et al.*** **[(9)]**.

The most common presentation was SAH in 460 (82.6%) followed by other presentations like ptosis and headache in 97 (17.4 %) patients, this agree with the study conducted by ***Lehmann et al.*** **[(9)]** the most common presentation was SAH **(60.23%)** followed by Control after embolization of aneurysm **(19.38%)** and Investigation of un-ruptured aneurysm **(15.50%).**

In our study, we find the most involved site is P.Com aneurysm in **143 (25.7 %)** patients followed by A.Com aneurysm **141 (25.3 %)**, while the least involved one is par ophthalmic aneurysms in **6 (1.1 %)** patients This was in agreement with the studies conducted in 2013 by ***Lehmann et al.*** **[(9)]** and in contrast to ***Badr et al.*** **[(11)]** that found majority of involved sites at A.com aneurysm followed by P.com aneurysm.

We found complications in 7 (1.2 %) of the patients classified into 3 (0.5 %) with groin hematoma and 4 (0.7 %) with vasospasm. This was controversy to the study was done in 2010 by ***Thiex et al.*** **[(12)]** that found the percentage of complications is 3.4% of patients with 2.1 groin hematoma and 1.3% cases with vasospasm.

In our study about AVM, the mean age of the patients (27.13±10.10), 259 (59.5%) were males and 176 (40.5%) were females, while in a different study done by ***Badr et al.*** **[(11)]** The 21 patients with Arteriovenous malformation out of which (33%) 7 were females and (67%) 14 were males with ages ranging from 2nd to 4th decade, as a result the AVM appear more in younger patients between (10-30) years younger than those with aneurysm **[(11)].**

In our study, we found 17(3.9 %) patients with normal finding and 321 (73.8 %) patients with anterior circulation AVMs 79 (18.2 %) with posterior circualation AVM, 13 (3%) with carotid-cavernous fistula and 5 (1.1 %) with vein of gallen malformation with no complications in these patient.

When we compare results of CTA with results of DSA in AVM, we find accuracy rate of CTA around (50%) with high sensitivity in carotid cavernous fistula (100%) then ant. circulation AVM (66. %) while CTA were less accurate in other types of AVM.

This in contrast to previous study done by ***Kokkinis et al.*** **[13]** where they found sensitivity, positive predictive accuracy and negative predictive accuracy for CTA was 98%, 97.9%, 100% and 94.3% and for DSA was 99%, 99.3%, 100% and 98%, respectively and concluded that CTA is a reliable alternative to DSA in detecting AVM **[13].** This may due to no quality of CTA in our country**.**

In the study done by ***Junliget et al.*** **[14]** (76%) with suspected AVM were proven to have arteriovenous malformation, in catheter based angiography (90%) were proven to have AVM. In addition, 3 patients out of 5 with suspected AVM in CTA were proven by catheter based angiography. The specificity of CTA for picking up AVM is (76%) 16 patients out of 21. The false positive cases were (10%) with No false negative cases in CTA. The sensitivity and specificity of catheter based angiography for picking up AVM is (100%) **[14]**.

CONCLUSION

Arterial stenosis is more common than cerebral aneurysms and AVM in the patients who subjected to DSA. The presence of hypertension and diabetes mellitus was found to be significantly more prevalent among patients with arterial stenosis. However, the prevalence of hypertension and smoking was more prevalent in cerebral aneurysms. In our population, the most common presentation of the patients subjected to DSA was ischemic stoke followed by SAH.

Good selection of patients with indications for cerebral catheter angiography and good selection of material used help in decreasing the complications. CT angiography of the cerebral blood vessels is the most accurate precath. Imaging in detection of arterial stenosis, cerebral aneurysms, AVM. Cerebral catheter angiography is a safe, feasible and efficacious procedure. Cerebral Catheter angiography is the gold standard method for diagnosis of stenosis & vascular malformations especially before therapeutic intervention.

REFERENCES

1. **Thierfelder KM, Havla L, Beyer SE, Ertl-Wagner B, Meinel FG, von Baumgarten L and Sommer WH (2015):** Color-coded cerebral computed tomographic angiography: Implementation of a convolution-based algorithm and first clinical evaluation in patients with acute ischemic stroke. Investigative Radiology, 50(5): 361-3.
2. **Flügel AK, Steiner T, Schill J, Jahangir N, Chughtai M, Qureshi MH and Qureshi AI (2016):** Hemorrhagic strokes. International Neurology, 28-36.
3. **Misher JM, Galmer AM, Weinberg MW, Pellerito JS and Lau JF (2017):** Re-evaluating the Appropriateness of Non-invasive Arterial Vascular Imaging and Diagnostic Modalities. Current Treatment Options in Cardiovascular Medicine, 19(8): 63-70.
4. **Philipp LR, McCracken DJ, McCracken CE, Halani SH, Lovasik BP, Salehani AA and Pradilla G (2017):** Comparison between CTA and digital subtraction angiography in the diagnosis of ruptured aneurysms. Neurosurgery, 80(5): 769-777.
5. **Schneider T, Wyse E, Lin D and Pearl MS (2014):** Role of cerebral angiography and review of endovascular treatment options in moyamoya disease and syndrome. Journal of Pediatric Neuroradiology, 3(1): 39-48.
6. **Di Gioia G, Scordino D, Campanale CM, Miglionico M, Creta A, Proscia C and Di Sciascio G (2016):** In-stent restenosis after carotid artery stenting: from diagnosis to treatment. EMJ., 1(3): 118-124.
7. **Cobb MI, Brown PA, Smith TP, Zomorodi AR and Gonzalez LF (2016):** Vascular Interventional Neuro-angiography. In Pediatric Vascular Neurosurgery, Springer International Publishing, 111-123.
8. **Dawkins A, Evans AL, Wattam J, Romanowski CAJ, Connolly DJA, Hodgson TJ, Coley SC (2007):** Complications of cerebral angiography: a prospective analysis of 2,924 consecutive procedures. Neuroradiology, 49:753–759.
9. **Lehmann MF, Aguiar PHP, Parreira JS, Antonucci AT, Santiago N, Lehmann ALCF, Reiche EMV, Maciel DRK (2013):** Complications of Cerebral Angiography Performed at a University Hospital, J Bras Neurocirurg., 24 (3): 194 – 200.
10. **Sacco RL, Kasner SE, Broderick JP, Caplan LR, Culebras A, Elkind MS and Janis LS (2013):** An updated definition of stroke for the 21st century. Stroke, 44(7): 2064-2089.
11. **Badr SM, Ahmed Z, Khafaji MA, Alsafi KGH, Abbas HY, Jastaniah SD (2014):** Computed Tomography Angiography Compared to Catheter Based Angiography in Evaluation of Cerebral Arterial Aneurysm and Arteriovenous Malformation**,** Open Journal of Medical Imaging, 4: 117-125.
12. **Thiex R, Norbash AM, Frerichs KU (2010):** The safety of dedicated-team catheter-based diagnostic cerebral angiography in the era of advanced noninvasive imaging. American Journal of Neuroradiology, 31(2):230-4.
13. **Kokkinis C, Vlychou M, Zavras GM, Hadjigeorgiou GM, Papadimitriou A and Fezoulidis IV (2008):** The Role of 3D-Computed Tomography Angiography (3D-CTA) in Investigation of Spontaneous Subarachnoid Hemorrhage: Comparison with Digital Subtraction Angiography (DSA) and Surgical Findings. British Journal of Neurosurgery, 22: 71-78.
14. **Junliget X, Dapeng S, Chuanliang C, Yongli L, Meiyun W, Xinwei H, Lixin J and Xiaoming B (2011):** Noncontrast-Enhanced Four-Dimensional MR Angiography for the Evaluation of Cerebral Arteriovenous Malformation: A Preliminary Trial, Journal of Magnetic Resonance Imaging, 34:1199–1205.