What can 3D CT angiography add in evaluation of facial vascular lesions?

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Vascular lesions of head and neck;
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Abstract
Purpose: To demonstrate the value of 3D CT angiography (CTA) in the evaluation of facial vascular lesions regarding diagnosis, characterization and full extensions compared to conventional 2D CTA.

Patients and methods: This prospective study included 16 patients with facial vascular lesions with ages that range from 1 to 45 years and mean age of 23 years, patients performed CT angiography (2D and 3D) utilizing the coronal and sagittal MPR and VR techniques. Lesions were evaluated by both 2D and 3D sequences regarding characterization and complete extension including intracranial extension. Our results were correlated with maxillofacial and plastic surgery results.

Results: Among the 16 patients, 7 had hemangiomas, 5 had AVMs and 4 had AVFs. In hemangiomas, 2D successfully evaluated (regarding diagnosis, characterization and full extensions) 5 patients (71.5%) and 2 patients were in doubt regarding diagnosis, while 3D CTA successfully evaluated all the patients (100%). In AVMs, 2D CTA successfully evaluated 4 patients (80%), one patient was in doubt regarding intracranial extension, while 3D CTA successfully evaluated all the patients (100%). In AVFs, 2D and 3D CTA successfully evaluated all the patients (100%). For all cases, diagnostic accuracy of 2D CTA was 81.3%, while diagnostic accuracy of 3D CTA was 100%.

Abbreviations: AVF, arteriovenous fistula; AVM, arteriovenous malformation; CA, conventional angiography; CTA, CT angiography; ECA, external carotid artery; ICA, internal carotid artery; MIP, maximum intensity projection; MRA, magnetic resonance angiography; SOF, superior orbital fissure; VR, volume-rendering.

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1. Introduction

The complex anatomy of the head and neck can make it difficult for the surgeon to be fully oriented by the vascular lesions in this region. Vascular lesions can be difficult to diagnose and classify. Accurate classification is important because treatments and prognosis vary based on the type of lesion. Diagnosis is based on a combination of clinical features with a variety of imaging techniques, including Doppler US, CT/CTA, MRI/MRA and conventional angiography (1–3). Duplex scanning visualizes superficial lesions and determines flow characteristics. Conventional CT measures bone and soft tissue density, but vascular lesions are poorly visualized, due to a slow image acquisition rate (4–5).

Magnetic resonance imaging (MRI) characterizes soft tissue tumor architecture, but is limited when the tumor involves bone. MR angiography is semi-invasive and accurate but is time consuming and not appropriate in an acute setting and the presence of intramural calcium leads to creation of magnetic field in homogeneities. MRA has many disadvantages like longer imaging time leading to motion and pulsation artifacts, exaggeration of stenosis with inability to depict true lumen of vessels in areas of turbulence (8–11).

Angiography is the gold standard for diagnosis but DSA is invasive, time-consuming, traumatic, relatively high cost and carries a small (1.3%) yet significant risk of neurologic morbidity (6,7).

CTA has become clinically useful due to advances in CT image acquisition. With the ability to obtain images in seconds, careful timing of intravenous contrast administration with directed imaging results in capture of contrast within the vascular lesions, as well as feeding vessels and draining veins. CTA with three-dimensional (3D) reconstructions can provide an exquisite overview of many of these lesions. CTA with 3D reformations considered a first-line evaluation and a follow-up bone for treated lesions (12–15).

The development of CT scanning equipment with multiple parallel detector arrays has enabled semi-invasive dynamic visualization of the entire head circulation, maintaining excellent spatial and temporal resolutions. Imaging of AVM's need high temporal resolution of the arteries and veins to depict the feeding arteries, nidus and early draining veins. Today CT angiography is being used in the evaluation of the AVM nidus prior to radiosurgery planning and in follow-up of patients after surgical treatment (12–15).

1.1. Aim of the study

The aim of this study was to demonstrate the value of 3D CT angiography (CTA) in the evaluation of facial vascular lesions regarding diagnosis, characterization and full extensions compared to conventional 2D CTA.

2. Patients and methods

This prospective study was conducted at a private center in Mansoura during the period from May 2009 till November 2011, it included 16 patients (11 were females, 5 were males) with their ages that ranged from 1 year to 45 years with a mean of 23 years. Patients were referred from maxillofacial surgery and plastic surgery clinics of Mansoura University Hospital seeking CTA. Patients' complaint was facial, painless swelling that gradually increased in size. Bruit and thrill were present in AVMs and AVFs, reddish skin discoloration in hemangiomas.

History of blunt trauma was found in 2 patients of AVF, other lesions were congenital. Our results were compared with physicians' results. Treatment of hemangiomas was by surgical excision, AVMs and AVFs were embolized and excised. No history of previous embolization or ligation or excision of these lesions.

2.1. Technique of CTA

Scanning of all patients was performed using 16-row General Electric bright Speed CT scanner (General Electric Medical Systems, Milwaukee, WI). An initial scout image was obtained to determine the scan volume. Proper timing is critical to ensure that the arterial system is maximally enhanced with no contamination by venous phase. In our study the optimum delay time was calculated by automated bolus tracking technique in all patients wherein the machine automatically starts scanning once the level of contrast enhancement in the artery (aortic arch) reaches a preset value of 65–70 HU.

A single bolus of 2 ml/kg of scanlux (non-ionic contrast material with 370 mg iodine/mL) was administered intravenously by power injector through a 20–22 gauge cannula located in an adequate superficial vein. Contrast material injected at a rate of 3–4 mL/s. All patients were examined in supine position. Images included head and neck to the thoracic inlet.

Scanning parameters were: section thickness: 0.65 mm/K.V:120/mAs:75–120/pitch: 1–1.5 and gantry rotation time 0.5 s.

About 800–1200 axial images/study were generated. The images were then transferred to an advantage workstation, the axial source data were post processed for display in 2D multiplanar reformat and 3D volume-rendering algorithms techniques. Images included bilateral internal and external carotid arteries and the vertebrobasilar artery. All studies were interpreted by the two radiologists independently.
The study protocol was approved by the ethical committee of our university and all the patients and children patients' parents gave informed consent.

2.2. Image analysis

In each case, all CTA images (2D: axial, coronal, sagittal and 3D VR images) were studied regarding lesion location, size, feeding arteries, nidus (if present) venous drainage, relations to nearby structures and full extensions especially intracranial extension. Complications were carefully looked for, e.g.: hemorrhage, brain and muscles atrophy, calcifications, bone erosions and flow related aneurysms.

3. Results

Our study included 16 patients with facial vascular lesions at the subcutaneous tissue, they were: 7 non-involuting Hemangioma, 5 AVM, and 4 AVF.

The 7 patients of hemangiomas were: 3 Peri-orbital, 2 nasolabial fold, one frontal and one peri-auricular. In 2D images they showed well defined lobulated masses that showed intense enhancement, 2 cases showed faint calcifications. 3D reformat showed a mass with two to three feeding vessels entering the mass perpendicularly. The draining veins were normal in caliber and non-tortuous.

*Confident diagnosis and full extensions were reached in all the cases with 3D reformat, while in 2D images, 5 patients were confidently diagnosed and 2 patients were unconfidently diagnosed (Figs. 1 and 2).

The 5 patients of AVMs were 2 temporal/peri-orbital, 2 maxillary, 1 nasal. In 2D images they showed ill defined masses that showed intense enhancement and dilated nearby tortuous vessels. 3D reformat showed a tangle of disorganized, tortuous vessels: feeding arteries and draining veins with vascular network in between (nidus). Feeding or draining vessels were abnormally disorganized, dilated, and tortuous.

*Confident diagnosis and full extensions were reached in all the cases with 3D reformat, while in 2D images, extension was fully oriented in 4 patients and one patient had doubted extensions (Figs. 3 and 4).

The 4 patients AVFs were 3 at the maxillary and 1 at the mandibular angle regions. In both 2D images and 3D reformat they showed saccular or fusiform dilatation of a vein connected directly to the nearby artery.

Female child aged 7 years presented with LT. temporal mass that gradually increased in size.

A-C: Axial & coronal 2D CTA showing intensely enhancing well defined lobulated mass at the subcutaneous tissue of RT. peri orbital & temporal regions. No underlying bone destruction. Note arterial supply from ipsilateral ophthalmic artery (arrow) and superficial temporal artery (arrow head).

D-G: 3D VR CTA showing the spectacular appearance of the hemangioma with feeding arteries: superficial temporal (arrow), maxillary (curved arrow) and mandibular (arrow head) branches of ECA, ophthalmic branch (double arrows) of ICA, entering the mass at nearly right angle. Venous drainage to RT. facial, external and internal jugular veins (not shown).

Fig. 1 A–G: A case of RT. Temporal non-involuting congenital hemangioma with both intra and extracranial arterial supply and extracranial venous drainage.
Confident diagnosis and full extensions were reached in all the cases with both 2D and 3D reformats (Fig. 5). These imaging data of 2D and 3D CTA were shown in Table 1.

Mid line lesions were supplied from both sides, while unilateral lesions had ipsilateral blood supply.

3D CTA clearly demonstrated the feeding arteries (from ECA) and draining veins in hemangioma, AVMs, AVFs patients, these findings were shown at Table 2.

Three patients with AVM showed intracranial extension (2 peri-orbital and temporal and one peri-auralic). Both 2D and 3D CTA clearly depicted the intracranial extension of the vascular lesions except in one patient. 3D provided more comprehension of the vessels course. The intracranial vasculature was shown in Table 3.

CTA source images offered additional information regarding brain parenchyma (to detect hemorrhage, ischemia, calcifications and atrophy) and neck muscles (to detect atrophy, calcifications). CTA offered topographic view visualizing the wall of the vessels, their lumen and nearby structures.

3D CTA successfully diagnosed and characterized all the cases with full assessment of the extensions including the intracranial extensions.

4. Discussion

Accurate classification of vascular malformations can be difficult but it is important because treatments and prognosis vary based on the type of lesion (1–3). Imaging strategies in the assessment of vascular lesions include sonography, CT/CTA, MR/MRA and digital subtraction angiography (DSA). Although the latter is the criterion-standard examination, it is an invasive procedure with a small but definite risk of stroke (1.3%), additionally, DSA will characterize only the patent

<p>| Table 1 | Showing 2D and 3D CTA imaging data for the study patients. |</p>
<table>
<thead>
<tr>
<th>Lesions</th>
<th>CTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemangiomas (7)</td>
<td>CTA findings</td>
</tr>
<tr>
<td>Confident diagnosis</td>
<td>2D CTA (axial, coronal, sagittal)</td>
</tr>
<tr>
<td></td>
<td>Well defined masses with intense enhancement ± calcifications.</td>
</tr>
<tr>
<td></td>
<td>5 (71.5%)</td>
</tr>
<tr>
<td>AVMs (5)</td>
<td>Masses with two to three feeding vessels entering the mass perpendicularly, no dilated veins</td>
</tr>
<tr>
<td>Confident diagnosis</td>
<td>7 (100%)</td>
</tr>
<tr>
<td></td>
<td>A tangle of disorganized, tortuous vessels: feeding arteries and draining veins with vascular network in between (nidus). Feeding or draining vessels were disorganized, dilated, and tortuous</td>
</tr>
<tr>
<td></td>
<td>5 (100%)</td>
</tr>
<tr>
<td>AVFs (4)</td>
<td>Saccular or fusiform dilatation of a vein connected directly to a nearby artery</td>
</tr>
<tr>
<td>Confident diagnosis</td>
<td>4 (100%)</td>
</tr>
<tr>
<td>Final diagnosis</td>
<td>13 (81.3%)</td>
</tr>
</tbody>
</table>

<p>| Table 2 | Showing 3D CTA vascular evaluation of the study patients. |</p>
<table>
<thead>
<tr>
<th>Lesions</th>
<th>CTA findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemangioma</td>
<td>Feeding arteries from ECA</td>
</tr>
<tr>
<td>Peri-orbital (3)</td>
<td>-Sup.temp, frontal</td>
</tr>
<tr>
<td>Naso-labial fold (2)</td>
<td>-Sup.temp, int.maxillary, frontal</td>
</tr>
<tr>
<td>Frontal (1)</td>
<td>-Facial</td>
</tr>
<tr>
<td>Peri-auricular(1)</td>
<td>-Post.auricular, mandibular</td>
</tr>
<tr>
<td>AVM</td>
<td>-Facial, external</td>
</tr>
<tr>
<td>Temporal/periorbital (2), Maxillary (2)</td>
<td>-Int.maxillary, sup.temp</td>
</tr>
<tr>
<td>Nasal (1)</td>
<td>Jugular, internal</td>
</tr>
<tr>
<td>AVF</td>
<td>-Facial, external</td>
</tr>
<tr>
<td>Maxillary (2), mandible angle (1)</td>
<td>ECA</td>
</tr>
</tbody>
</table>

<p>| Table 3 | Showing intracranial vasculature of 3 AVMs as detected by 3D CTA. |</p>
<table>
<thead>
<tr>
<th>Sites</th>
<th>CTA findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-cranial feeding arteries (from ICA)</td>
<td>Nidus size in mm</td>
</tr>
<tr>
<td>Temporal and peri-orbital</td>
<td>Ophthalmic, branches of middle cerebral arteries.</td>
</tr>
<tr>
<td>Periauricular</td>
<td>Caroticotympanic artery</td>
</tr>
<tr>
<td></td>
<td>3–15</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Internal jugular vein, ext.jug.vein</td>
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</table>
component of the vascular lesion, which can lead to an underestimation of lumen size depending on the degree of thrombus within the lesion (16–18). Sonography has been used to detect superficial vascular lesions but sonography provides little information about the adjacent soft tissues and osseous structures. MR angiography (MRA) is a noninvasive but expensive imaging tool that can highlight the soft tissue abnormality and its relationship to the adjacent soft tissues. Turbulent flow within a vascular lesion could result in intervoxel dephasing, which could underestimate the size of the lesion or overestimate the amount of thrombosis, in addition MRA is poor in calcifications and bone abnormalities detection (18–20).

CTA is often chosen as the initial imaging tool for head and neck vascular lesions. CTA is superior to US and MRI in spatial and temporal resolutions and 3D formatting, better defining the gross total anatomy and the relationship to important structures in the head and neck both soft tissue and bones. This aids both surgical planning and patient follow up. CTA is a minimally invasive technique that has evolved simultaneously with advances in CT technology, like multi-detector system. Postprocessing software is robust and includes 2D and 3D assessments in an indefinite number of planes (16).

In facial vascular lesions, CT angiography accurately depicted the patency, position, size of the vessels. The adjacent bones are easily assessed for fractures, erosions and any potential communication with the intracranial compartment (16–20).

The classic non-involuting congenital hemangioma is a benign vascular tumor that is small or absent at birth and then proliferates over a period of years, affecting females more than males. Involuting type usually regresses spontaneously. The 2D images in patients with hemangiomas showed brightly enhancing lesions. The 3D reformations showed a distinct appearance of a lobulated mass with two to three feeding vessels entering the mass perpendicularly, a finding that has been described angiographically in infantile hemangiomas. The surface texture of the mass on 3D is quite distinctive, resembling the surface of a head of cauliflower. There is no enlargement or tortuosity of the feeding vessels, which had an orderly appearance, entering the lesion at right angles (1–3).

Our study revealed similar results, in 2D CTA, hemangiomas show well defined lobulated masses with intense enhancement associated with or without calcifications. 3D reformat shows a mass with two to three feeding vessels entering the mass perpendicularly. Draining veins were normal in caliber and non-tortuous. 2D CTA successfully evaluated 5 out of 7 patients (71.5%) while 3D CTA successfully evaluated all the patients (100%).

2D CTA offers little characterization of the mass as it is merely an intensely enhancing mass with no characteristic features, but the 3D reformat offers a characteristic appearance specific for hemangiomas (Figs. 1 and 2).

Congenital AVMs present at birth, enlarge in proportion to the child, and do not undergo spontaneous regression, usually manifest late in life and require treatment, have no sex predilection. They are considered a lesion of abnormally formed vascular channels and can be subdivided into subtypes based on the channels type histologically (e.g., venous, arteriove-
nous, capillary, lymphatic, and mixed). Vascular malformations are also classified into high-flow (AVM) and low-flow (venous malformations) lesions based on flow velocity. These classifications are important in guiding treatment and in prognosis (20–22). The AVM is composed of a central nidus with anomalous arterio-venous shunts and a network of surrounding collateral vessels. In 2D CTA, it appears as a brightly enhancing lesion. On 3D reformations, however, it appears as a tangle of disorganized vessels rather than the discrete mass appearance of the hemangiomas. Nearby feeding or draining vessels were abnormally disorganized, prominent, and tortuous (22–24).

Our study revealed the same imaging features. In 2D images they showed as ill defined masses that showed intense enhancement and dilated nearby tortuous vessels. 3D reformat showed a tangle of disorganized, tortuous vessels feeding arteries and draining veins with vascular network in between (nidus). Feeding or draining vessels were abnormally disorganized, dilated, and tortuous. 2D CTA successfully evaluated in 4 out of 5 patients (80%) while 3D CTA successfully evaluated all the patients (100%).

In 2D images, adequate identification of feeding arteries and draining veins was possible (except in one patient) but with a lot of effort, while identification of feeding arteries, draining veins was easy and accurate with 3D reformations (Fig. 3).

3D CTA clearly demonstrated AVMs with intracranial extension, it offered excellent mapping of the feeding arteries and draining veins (20–25).

In our study, 3D CTA successfully evaluated all the three cases with intracranial extensions, offered excellent orientation of the intracranial vasculature (Fig. 4).

An AVF forms when the vaso-vasorum is abnormally formed or damaged, leading to arterial wall necrosis and abnormal vascular endothelial proliferation to an adjacent vein, AVF shows clinically continuous thrill and a bruit. In 2D CTA, they appear as saccular or fusiform intensely enhancing structure in direct communication with the nearby artery. 3D CTA offered excellent view for the dilated early appearing vein connected to the nearby artery (16,26).

Our study revealed the same imaging features, in both 2D and 3D CTA, they appeared as saccular or fusiform intensely enhancing venous structure in direct communication with the nearby artery. 3D CTA offered excellent topographic view for the dilated, early appearing vein connected to the nearby artery, 2D and 3D CTA successfully evaluated all cases (100%), but 3D CTA offered excellent orientation of the vessels course (Fig. 5).

Volume-rendered reformatting is helpful in categorizing clinically significant vascular head and neck lesions, resulting in more diagnostic value than planar CT imaging alone. In particular, 3D CTA might allow accurate differentiation of
hemangiomas from AVM, and of lymphangiomas from other types of lesions, which was not possible using clinical examination or conventional planar CT angiography (1). VR technique in our study revealed excellent resolution and high diagnostic value. 2D CTA successfully diagnosed and characterized 13 cases out of 16 (81.3%) while 3D CTA successfully diagnosed and characterized all cases (100%). 2D CTA could not characterize 2 cases of hemangioma close to bones and one patient with AVM with extensive, complex intracranial extension, 3D CTA successfully characterized these cases with excellent comprehension of the complex anatomy and vessels course.

In the study of Meifang et al., 2011 (27), they found that the sensitivity of CTA in the diagnosis of vascular disease was 98.4%, specificity was 99.4%, false-positive was 1.1% and false negative was 0.9%. CTA examination showed high specificity, sensitivity and low rate of misdiagnosis, compared with DSA, no significant difference was found between CTA and DSA. CTA in our study successfully detected and characterized all vascular lesions without the need for invasive DSA.

Perkinsa et al., 2005 (4) mentioned that, the exact radiation dose used with multislice CT scanners is difficult to determine and varies among institutions. Compared with the old single slice scanners, the dose from multislice would be higher if the same scan parameters were used. However, they were able to get good images with lower mAs with multislice, so eventually the dose was not high (4). In our study we used mAs less than 150 as a trial to reduce radiation dose.

Yanga et al., 2008 (28) in their study stated that multiphase-CTA (MP-CTA) was significantly better than single phase-CTA(SP-CTA) in vascular enhancement and in the absence of venous contamination. Multiphase-CTA used less
CTA offered noninvasive excellent angiographic imaging modality of the facial vascular lesions. The 3D CTA in particular (with high spatial and temporal resolution) provided distinct features that enabled excellent lesion detection, characterization, visualization of feeding arteries and draining veins and complete extensions. The 3D CTA allowed accurate differentiation of hemangiomas from AVMs that is sometimes difficult using clinical examination and 2D CTA. The 3D CTA plays an important role in extension evaluation, treatment planning (through full orientation of vascular tree) and follow up, thus eliminates the need for invasive DSA.

5. Conclusion

Contrast medium than single phase-CTA and could demonstrate hemodynamic information. The effective radiation dose of MP-CTA was 5.73 mSv, which was equal to that in conventional perfusion CT, and it was 3.57 mSv in SP-CTA using sampling interval of 0.5 s, but when using a sampling interval of 1 s radiation dose of both techniques would be the same.

Limitations of our study include limited patient’s number that probably lead to low diagnostic accuracy of 2D CTA and limited pathological types. We are hoping in the near future to use multi-phase CTA technique to reduce contrast amount and better appreciation of hemodynamics.

References


A-C: Axial, coronal and coronal oblique 2D CTA showing saccular dilatation of the proximal part of LT. internal jugular vein (arrow).

D,E: 3D VR CTA showing saccular dilatation of LT. internal jugular (arrow head) & external jugular vein (double arrow) connected to external carotid artery (arrow) branch of CCA (curved arrow).

Fig. 5 A–E: A case of traumatic LT. Maxillary AVF.
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