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RESEARCH ARTICLE

Efficacy of cone-beam computed tomography for the treatment of cerebral aneurysms with flow diverter

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Abstract

Cone beam computed tomography (CBCT) has evolved to provide details of implanted devices such as flow diverters when they are used for the treatment of cerebral aneurysms. The study aims to present our experience in using CBCT with intra-arterial injection and provide a step-by-step approach for postprocessing in a practical protocol for daily use. IRB approval was obtained, and the neuro-interventional database of the year 2022 was retrospectively reviewed for patients who were treated for cerebral aneurysms with flow diverters. Patient demographics, aneurysm location (internal carotid artery [ICA]-ophthalmic artery [OphA], posterior communicating artery [PCoA], anterior communicating artery [ACoA]), type (regular, bilobed or fusiform), size, device, injection technique (contrast dilution, rate, and volume), and reconstruction protocol were recorded. Acquired images were postprocessed using a Philips Xtravision workstation. Five patients (three women and two men) met the criteria of our study. One patient was treated for two aneurysms simultaneously. The age range was 50-80 years old. The device's landing zones, wall apposition and neck coverage were successfully visualized in all cases. After six months a complete aneurysm exclusion was obtained in two cases.

Introduction

Interventional radiology has always used bidimensional radiographic techniques such as digital subtraction angiography (DSA) and fluoroscopy to visualize, manipulate and study tridimensional structures [1]. Due to the complexity of the vascular anatomy and to perform angiographic procedures such as stent positioning, mechanic thrombectomy, and aneurism embolization but also extravascular treatments like the radiofrequency ablation, a more comprehensive and accurate characterization of the vessels and their perivascular structures are necessary. Efforts were made to develop a 3D data generation system suitable for interventional radiography. Computed rotational 3D DSA allows a 3D rendering of digitally subtracted contrast-enhanced vessels. With this technique, multiple projection angles are obtained by rotating a conventional angiography unit around the patient and a cone-beam back projection reconstruction algorithm generates the three-dimensional images [2-3]. Within a short period, 3D digital angiography was developed to obtain a 3D visualization of high-contrast structures including the bone tissue and contrast-enhanced vessels. This technique uses unsubtracted rotational images producing fewer artifacts and requiring lower patient dose over 3D DSA (Toshinori Hirai, 2003). However, the visualization of low-contrast structures is still limited. By fusing an angiographic system with a fan-beam scanner CT, an angio-CT system was developed and of particular value was the development of the cone-beam CT (CBCT) [4-5-6].

The basic principle of CBCT is the acquisition of multiple X-ray projections during a single gantry rotation around a volume of interest, usually spanning a total of 200 degrees. The resulting series of images is back-projected to produce a volumetric dataset [2][7-8](Figure 1).

In CBCT, the beam forms a conical geometry between the source and the detector and acquires the information using a high-resolution two-dimensional detector (Figure 2a); otherwise, in fan-beam acquisition, the collimator limits the x-ray beam to a 2D geometry and uses multiple elements of one-dimensional (1D) detectors to acquire images (Figure 2b) [1].

This particular layout is more suitable for interventional radiology for different reasons: the system is compact enough to be mounted on a mobile c-arc so the patient can be still during the exam. In one single orbit around the patient, a complete volumetric dataset is generated covering a large anatomic region of interest [9]. Submillimeter isotropic re-

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Figure 1. *Commercial C-arm mounted flat panel detector cone-beam CT system.*

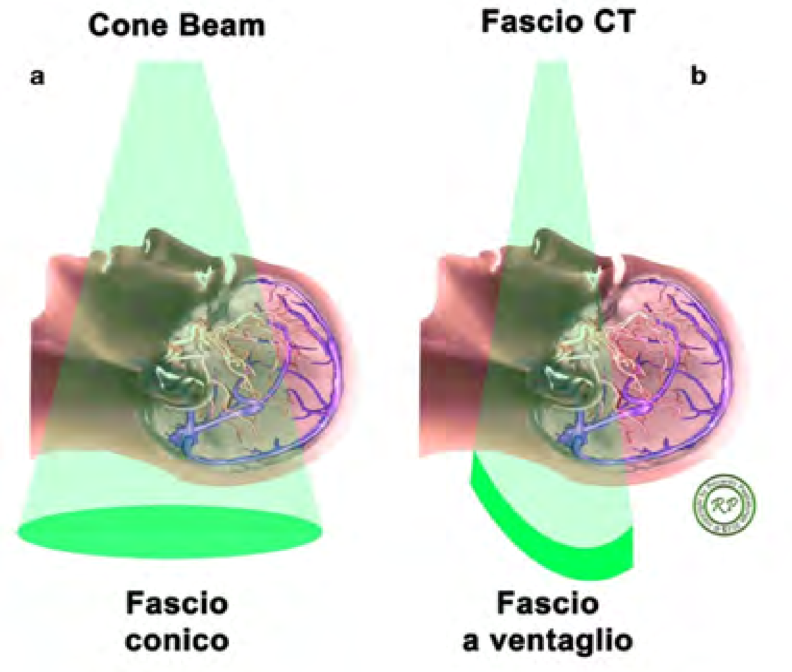

Figure 2. **a)** *Cone-beam Geometry*. **b)** *Fan-beam geometry*

constructions can be created with this technique. High-efficiency two-dimensional detector allows an excellent recognition of low-contrast structures. For C-arm CBCT systems, current detector arrays are 40x30cm2, allowing 25x25x18cm3 volumetric datasets to be generated in a single rotation of the source and detector [1]. A more comprehensive characterization of neurovascular diseases can be obtained using HR-CBCT [3] [10].

Materials and Methods

We enlisted five consecutive cases admitted to our Hospital in 2022 to evaluate the efficacy of CBCT for the treatment of cerebral aneurysms with flow-diverter. All the procedures were performed under general anaesthesia using a flat-panel monoplane angiographer (Philips Allure FD20). Patient demographics, aneurysm location (internal carotid artery [ICA]-ophthalmic artery [OphA], posterior communicating artery [PCoA], anterior communicating artery [ACoA]), type (regular, bilobed or fusiform), size, device, injection technique (contrast dilution, rate, and volume), and reconstruction protocol were recorded as described in Table 1. Acquired images were postprocessed using a Philips Xtravision workstation (Philips Healthcare). The area of interest was positioned in the centre of rotation, with the catheter previously in place within the ipsilateral internal carotid artery (ICA) or the vertebral artery (VA). The acquisition was obtained using the CBCT ICS 22 algorithm protocol available in our equipment. One injection technique was used: 1.5 ml/s for a total volume of 38 ml with a 4-s imaging delay. Contrast Iomeron 300 mg/mL (Bracco Imaging) dilution was 10%. An algorithm (O-Mar, Philips) was applied to reduce metal artefacts from the implanted devices. Through a qualitative description, we have evaluated the following parameters: side branch coverage, neck coverage and wall-malposition of the devices.

Results and Discussion

Of 40 patients treated for cerebral aneurysms in our institution, 5 patients met the inclusion criteria for our study. There were a total of 3 women (60%) and two men (40%). One patient was treated for two aneurysms simultaneously. The aneurysms were located in the ICA-ophthalmic artery in four cases, PCoA in one case, and ACoA in one case. Four were bilobed aneurysms, one regular and one fusiform. PED-Vantage (two cases), Silk-Vista (two cases), Surpass-Evolve (one case), and Derivo-Mini (one case) were the devices used during the procedures. With CBCT were accurately visualized the landing zones, conformability to the arterial geometry and aneurysm neck in all cases. In four cases only OphA was covered. In one case both OphA and AChA were covered. Wall malposition was present in four cases. Good neck coverage was observed in four cases. Six months follow-up showed aneurysm exclusion in two cases. Intimal hyperplasia was detected in one case (Tab. 2).

Pazient	**Age**	**Sex**	**Location of the Aneurism**	**Size of the Aneurism**	**Type of the Aneurism**	**Type of Flow-diverter**	**Diameter of flow-diverter. (mm)**	**Length of flow-diverter. (mm)**
Case 1	57	*M*	*ICA-OphA*	6x5	*Regular*	*PED-Vantage*	4.5	20
Case 2.1	52	*F*	*ICA-OphA*	4x4	*Regular*	*Silk-Vista*	4	15
Case 2.2	52	*F*	*ICA-OphA*	8x6	*Bilobed*	*Silk-Vista*	4	15
Case 3	56	*M*	*ICA-OphA*	7x4	*Fusiform*	*Surpass-Evolve*	5	20
Case 4	77	*F*	*ICA-PCoA*	10x9	*Regular*	*PED-Vantage*	5	20
Case 5	58	*F*	*ACoA*	3x3	*Regular*	*Derivo-Mini*	25	15

Table1. *Patient demographics, location, type and size of the aneurysm, type, diameter and length of flow diverter.*

Patient	*Side branches coverage*	*Neck coverage*	*Wall-malposition*	*Angioplasty*	*Aneurysm exclusion during follow-up*	*Intimal hyperplasia.*
Case 1	*OphA*	*excellent*	*Proximal*	*No*	*Follow up non performed yet*	
Case 2.1	*OphA*	*Good*	*Distal*	*No*	*Excluded*	*No*
Case 2.2	*OphA*	*excellent*	*Distal*	*No*	*Excluded*	*No*
Case 3	*OphA*	*Good*	*Proximal*	*No*	*Not excluded in six months*	*No*
Case 4	*OphA e AChA*	*Good*	*No*	*No*	*Not excluded in six months*	*Moderate*
Case 5	*No*	*Good*	*No*	*No*	*Follow up non performed yet*	

Table 2. *Parameters*

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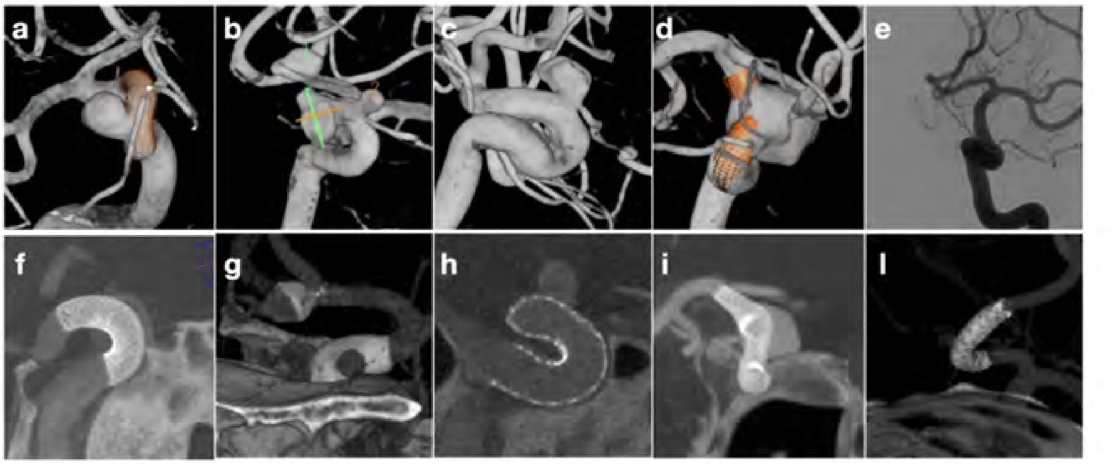

Figure 3. *a, b, c, d: pre-treatment CBCT images. e: pre-treatment DSA image. f, g, h, i, l: post-treatment CBCT images.*

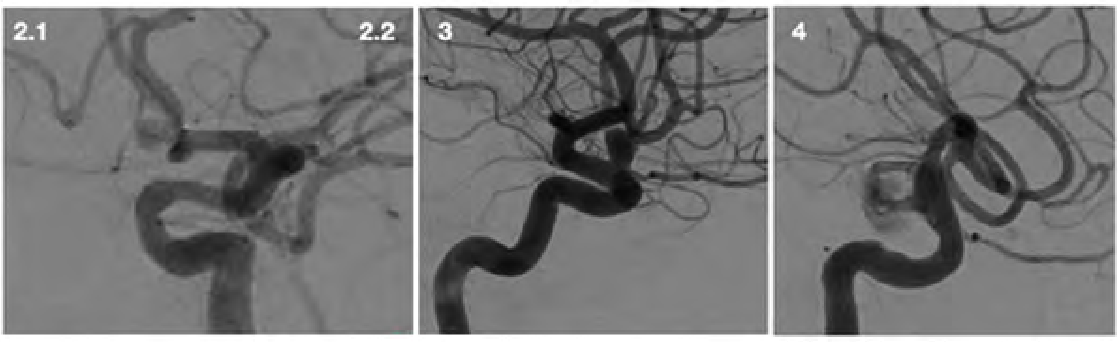

Figure 4. *Follow-up with DSA images. Case 2.1 e 2.2: excluded aneurysm. Case 3: not excluded aneurysm. Case 4: The aneurysm neck is narrowing because of the stent endothelialization.*

Currently, the evaluation of implanted intracranial devices is often performed using DSA and conventional CT/MR angiography techniques [11-12-13]. Despite the small size of our numerical sample, we found the practical applicability of cone beam CT with intra-arterial injection for the evaluation of implanted flow diverters. Another factor to consider is the technical limitation of the method, for example, stent postoperative evaluation with conventional angiography can be difficult because of the low density of the device [14-15-16]. In our study, all of the flow diverters deployed were perfectly visualized with the CBCT.
IA-CBCT imaging can provide details not only about the implanted device but also about the microvascular anatomy contributing to the decision-making during these procedures [16-17-18].
Despite the technical advantages, motion artifacts even from subtle movements can significantly degrade the processed images; in our study, this was not a factor because the patients were under general anesthesia [15]. Another advantage of this technique is the lower contrast agent dose; in fact, IA-CBCT imaging was obtained with a 10–20% diluted contrast [14-17]. Furthermore, IA-CBCT can be performed intraoperatively, allowing for real-time intervention adjustment by image data, unlike CT-MS and MRA [11-15]. In our study, this feature was instrumental in visualizing the tight anatomical relationships between the flow diverter, the aneurysm neck, and the parent vessel.
Patel et al submitted a standardized questionnaire, scoring the cases for the quality of visualization of a stent and the parent vessels by addressing: the stent wall apposition, filling defect of the stented segment and the presence of calcification [14]. We used the IA-CBCT imaging also for a qualitative evaluation of the procedures such as side branch coverage, neck coverage, and wall-malposition. This allowed further intervention and medical decision-making [18].
Being a retrospective study, its limitations are due to possible selection bias and the small size of our cases.

Conclusions

IA-CBCT provides high-quality imaging of the neurovascular and perivascular anatomy. It can be a valid peri and postoperative approach to evaluate the quality of the device's deployment so decisions can be made in real-time to resolve critical factors. Furthermore, this technology proves to be of considerable use during the procedure, as a preliminary moment for selecting the best projective image and for evaluating the best strategy for the procedure, also concerning preoperative planning.
The radiology technician, within the multidisciplinary team, assumes an important role, in the management of the technology, for the optimization

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of the dose, and the processing and production of the appropriate images. This aspect becomes even more meaningful when these technologies are used in the complementary field and therefore, not in the strictly radiological field, assuming a guaranteed function in the use of radiological technology.

Bibliography

1. 1.Robert C Orth, M. J., & Radiology, T. A. (2009). *C-arm cone-beam CT: general principles and technical considerations for use in interventional radiology. J Vasc Interv Radiol*, 20, S538-44.
2. *Albrecht Hochmuth, U. S.* (2002). *Comparison of three-dimensional rotational angiography with digital subtraction angiography in the assessment of ruptured cerebral aneurysms. AJNR Am J Neuroradiol.*, 23, 1199-205.
3. *Joon K Song, Y. N.* (2004). *Simultaneous bilateral internal carotid artery 3D rotational angiography. AJNR Am J Neuroradiol*, 25, 1787-9.
4. *Theocharis Berris, R. G.* (2013). *Radiation dose from cone-beam CT in neuroradiology applications. AJR Am J Roentgenol.*, 200, 755-61.
5. *D A Jaffray, J. H.* (2000). *Cone-beam computed tomography with a flat-panel imager: initial performance characterization. Med Phys*, 27, 1311-23.
6. *Z Rumboldt, W. H.* (2009). *Review of portable CT with assessment of a dedicated head CT scanner. AJNR Am J Neuroradiol*, 30, 1630-6.
7. *Masahiro Endo, S. M.* (2006). *Magnitude and effects of x-ray scatter in a 256-slice CT scanner. Med Phys.*, 33, 3359-68.
8. *Toshinori Hirai, Y. K.* (2003). *Clinical usefulness of unsubtracted 3D digital angiography compared with rotational digital angiography in the pretreatment evaluation of intracranial aneurysms. AJNR Am J Neuroradiol.*, 24, 1067-74.
9. *A C Miracle, S. K.* (2009). *Conebeam CT of the head and neck, part 2: clinical applications. AJNR Am J Neuroradiol*, 30, 1285-92.
10. *Eytan Raz, E. N.* (2023). *Principles, techniques and applications of high resolution cone beam CT angiography in the neuroangio suite. J Neurointerv Surg*, 15, 600-607.
11. *Osman Kizilkilic, N. K.* (2012). *Utility of VasoCT in the treatment of intracranial aneurysm with flow-diverter stents. J Neurosurg*, 117, 45-9.
12. *Wataro Tsuruta, Y. M.* (2013). *Analysis of closed-cell intracranial stent characteristics using cone-beam computed tomography with contrast material. Neurol Med Chir (Tokyo)*, 53, 403-8.
13. *Rudolph M Snoeren, M. S.* (2012). *High-resolution 3D X-ray imaging of intracranial nitinol stents. Neuroradiology*, 54, 155-62.
14. 14. *N V Patel, M. J.-K.* (2011). *Contrast-enhanced angiographic cone-beam CT of cerebrovascular stents: experimental optimization and clinical application. AJNR Am J Neuroradiol*, 32, 137-44.
15. *Sameer A Ansari, S. G.* (2012). *Cone beam computed tomography in the neurointerventional room: beyond vessels. World Neurosurg.*, 77, 659-61.
16. *Geoffrey P Colby, L.-M. L.* (2016). *Flow diversion of large internal carotid artery aneurysms with the surpass device: impressions and technical nuance from the initial North American experience. J Neurointerv Surg.*, 8, 279-86.
17. *K I Jo, S. R.* (2015). *Contrast-enhanced angiographic cone-beam computed tomography without pre-diluted contrast medium. Neuroradiology*, 57, 1121-6.
18. *Reiichi Ishikura, K. A.* (2006). *Evaluation of vascular supply with cone-beam computed tomography during intraarterial chemotherapy for a skull base tumor. Radiat Med.*, 24, 384-7.

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