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 X.tarition 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 aneurysm embolization but also extravascular treatments like the radiofrequency ablation, mechanic thrombectomy, and aneurysm embolization but also extravascular treatments like the radiofrequency ablation, maneuvers required images (Figure 2b) [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-arm 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-
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

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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
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-ophtalmic 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).

<table>
<thead>
<tr>
<th>Patient</th>
<th>Side branches coverage</th>
<th>Neck coverage</th>
<th>Wall-malposition</th>
<th>Angioplasty</th>
<th>Aneurysm exclusion during follow-up</th>
<th>Intimal hyperplasia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>OphA</td>
<td>excellent</td>
<td>Proximal</td>
<td>No</td>
<td>Follow up non performed yet</td>
<td></td>
</tr>
<tr>
<td>Case 2.1</td>
<td>OphA</td>
<td>Good</td>
<td>Distal</td>
<td>No</td>
<td>Excluded</td>
<td>No</td>
</tr>
<tr>
<td>Case 2.2</td>
<td>OphA</td>
<td>excellent</td>
<td>Distal</td>
<td>No</td>
<td>Excluded</td>
<td>No</td>
</tr>
<tr>
<td>Case 3</td>
<td>OphA</td>
<td>Good</td>
<td>Proximal</td>
<td>No</td>
<td>Not excluded in six months</td>
<td>No</td>
</tr>
<tr>
<td>Case 4</td>
<td>OphA e AChA</td>
<td>Good</td>
<td>No</td>
<td>No</td>
<td>Not excluded in six months</td>
<td>Moderate</td>
</tr>
<tr>
<td>Case 5</td>
<td>No</td>
<td>Good</td>
<td>No</td>
<td>No</td>
<td>Follow up non performed yet</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Parameters
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...
Bibliography


