Utility of Cone-Beam CT Imaging in Prostatic Artery Embolization

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ABSTRACT

Purpose: To evaluate the utility of cone-beam computed tomography (CT) in patients undergoing prostatic artery (PA) embolization (PAE) for benign prostatic hyperplasia.

Materials and Methods: From January 2012 to January 2013, 15 patients (age range, 59–81 y; mean, 68 y) with moderate- or severe-grade lower urinary tract symptoms, in whom medical management had failed were enrolled in a prospective United States trial to evaluate PAE. During pelvic angiography, 15 cone-beam CT acquisitions were performed in 11 patients, and digital subtraction angiography was performed in all patients. Cone-beam CT images were reviewed to assess for sites of potential nontarget embolization that impacted therapy, a pattern of enhancement on cone-beam CT suggesting additional PAs, confirmation of prostatic parenchymal perfusion before embolization, and contralateral prostatic parenchymal enhancement.

Results: Cone-beam CT was successful in 14 of 15 acquisitions, and PAE was successful in 14 of 15 patients (92%). Cone-beam CT provided information that impacted treatment in five of 11 patients (46%) by allowing for identification of sites of potential nontarget embolization. Duplicated prostatic arterial supply and contralateral perfusion were each identified in 21% of patients (three of 11). Prostatic perfusion was confirmed before embolization in 50% of acquisitions (seven of 14).

Conclusions: Cone-beam CT is a useful technique that can potentially mitigate the risk of nontarget embolization. During treatment, it can allow for the interventionalist to identify duplicated prostatic arterial supply or contralateral perfusion, which may be useful when evaluating a treatment failure.

ABBREVIATIONS

AUA = American Urological Association, BPH = benign prostatic hyperplasia, DSA = digital subtraction angiography, LUTS = lower urinary tract symptoms, PA = prostatic artery, PAE = prostatic artery embolization

Benign prostatic hyperplasia (BPH) affects more than 15 million men in the United States, with an annual health care cost of more than $3 billion (1,2). In BPH, the prostate enlarges secondary to smooth muscle and epithelial proliferation. Prostatic enlargement results in the symptom complex known as lower urinary tract symptoms (LUTS) from direct bladder outlet obstruction and increased smooth muscle tone and resistance. The LUTS complex includes nocturia, frequency, urgency, weak stream, intermittency, and incomplete bladder emptying.

Recently, prostatic artery (PA) embolization (PAE) has been studied to assess its risk profile and clinical success. Studies have thus far shown a significant reduction in LUTS in patients with BPH in whom medical therapy has failed, with the majority of patients having persistent symptom relief at 1 year (3,4). The procedure has been performed relatively safely, with no reports of sexual dysfunction, incontinence, or infection. One case of nontarget embolization to the bladder wall necessitating surgery has been published (4).

Preprocedural computed tomographic (CT) angiography has been used to perform planning before embolization (5,6). Benefits of this technique include identification of PA origins, tortuosity, and atherosclerotic disease, as well as the determination of optimal C-arm angulation for selective catheterization. Disadvantages of CT angiography include the lack of sensitivity in identifying...
small PAs, which may exclude potential candidates. Imaging also requires the administration of at least 100 mL of iodinated contrast medium. Previous reports have also noted that CT angiography studies have lacked cone-beam CT after selective PA angiography to confirm proper catheter positioning before embolization and have not compared procedure times with and without the use of preoperative CT angiography (6). The present study aims to identify the benefits of cone-beam CT during PAE. Specifically, focus was placed on the value of soft-tissue delineation during cone-beam CT and patterns of parenchymal perfusion that are encountered during treatment.

MATERIALS AND METHODS

In January 2012, a prospective institutional review board–approved phase II/III trial of PAE in the treatment of BPH was initiated. Written informed consent was obtained from all patients, and the study was compliant with the Health Insurance Portability and Accountability Act.

From January 2012 to January 2013, 15 patients aged 59–81 years with moderate- or severe-grade LUTS related to BPH were enrolled as part of a target enrollment of 30 patients. All patients were evaluated clinically by an interventional radiologist and urologist and underwent the following preprocedure evaluation: American Urological Association (AUA) symptom score testing, complete blood count, complete metabolic panel, prostate-specific antigen measurement, urodynamic testing, and prostate magnetic resonance imaging. Demographic details are summarized in Table 1. Patients with bladder or prostate carcinoma, renal insufficiency, coagulopathy, or a neurogenic bladder were excluded. PAE procedures were performed by a board-certified interventional radiologist per standardized protocol in a cone-beam CT–capable uniplanar flat-panel interventional suite (Artis zee; Siemens, Forchheim, Germany).

Procedures were performed with moderate conscious sedation and local anesthesia with continuous monitoring. Nonsteroidal antiinflammatory medication and oral antibiotic treatment were administered before the procedure. With a single common femoral artery access site, selective bilateral hypogastric artery catheterizations were performed with a 5-F Cobra catheter (Cook, Bloomington, Indiana), with subsequent digital subtraction angiography (DSA). Images were acquired per a standardized protocol: anterior/posterior and 30° ipsilateral oblique/10° caudad projection. A 2.5-F Renegade STC microcatheter (Boston Scientific, Natick, Massachusetts) and microwire (Glide GT double-angle and Headliner wire; Terumo, Somerset, New Jersey) were advanced coaxially to select the PA.

After selection of the target artery and before embolization, DSA and cone-beam CT were performed in 11 of 15 patients with the use of 1.5–2.0 mL of 100% iodinated contrast (Visipaque; GE Healthcare, Princeton, New Jersey) injected by hand over a period of 2–3 seconds with an imaging delay of 4–6 seconds (Fig 1). The imaging sequence used an 8-second rotational scan of 208° at 26° rotation per second with image acquisition every 0.5° and a source power of 125 kVp, resulting in a

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
<td>68 (59–81)</td>
</tr>
<tr>
<td>Baseline AUA symptom score</td>
<td>25 (14–35)</td>
</tr>
<tr>
<td>Prostate volume (cm³)</td>
<td>64</td>
</tr>
<tr>
<td>IIEF score</td>
<td>13 (3–30)</td>
</tr>
<tr>
<td>Peak urine flow (mL/s)</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Values in parentheses are ranges.

AUA = American Urological Association, IIEF = International Index of Erectile Function.

Figure 1. (a) Selective angiography of the left PA, arising from the obturator artery in this patient, with hypervascularly enlarged prostate gland. (b) Axial reformatted cone-beam CT with perfusion of the left hemiprostate, including the capsule and central and peripheral gland. (c) Coronal reformatted cone-beam CT demonstrates complete perfusion of the left hemiprostate, including a hypertrophic median lobe protruding into the bladder neck.
total of 417 matrix images (512 × 512 voxels). The receiver
dose was approximately 0.36 μGy per frame. Multiplanar
images were reviewed by using a soft-tissue algorithm and
5-mm-thick slices. Cone-beam CT acquisition and recon-
struction were performed by using Artis zee and syngo X
Workplace software, respectively (Siemens). Image proc-
essing and three-dimensional rendering were performed on
a Leonardo workstation (Siemens).

If a site of potential nontarget embolization was
identified, further selective catheterization was per-
formed before embolization. PAE was then performed
with the use of a spherical embolic agent (100–400-μm
Embozene; Celonova Biosciences, San Antonio, Texas)
to the extent of complete or near-complete stasis.

Images were reviewed intraoperatively to assess for
(i) cone-beam CT–identified sites of potential nontarget
embolization before embolization, (ii) pattern of enhan-
cement on cone-beam CT suggestive of additional PAs,
and (iii) cone-beam CT confirmation of prostatic paren-
chymal perfusion before embolization. Retrospective
review was performed to assess for contralateral prostatic
parenchymal enhancement. Images were also reviewed for
reflux of contrast agent proximal to the catheter tip, which
could falsely identify proximal branch vessels.

Figure 2. (a) Right anterior oblique projection from selective catheterization of the right hypogastric artery depicts what was believed (black arrow) to be the right PA, arising from the common gluteal–pudendal trunk. (b) Axial cone-beam CT after selective catheterization of this branch depicts well the inferior rectal artery, a potential site of nontarget embolization. Note the dense perfusion the inferior rectum and anus, with absence of prostate perfusion.

Figure 3. (a) DSA of the left superior vesical artery with vascularization of the central gland (black arrows) from a small distal branch of the vesicle artery (white dashed arrow). (b) Axial cone-beam CT depicts well the anterior and left lateral bladder wall perfusion, a site of potential nontarget embolization.
RESULTS

Pelvic angiography was performed in 15 patients, and PAE was technically successful in 14 (92%), as defined by at least unilateral embolization. One unsuccessful case was secondary to atherosclerotic occlusion of both PAs. Cone-beam CT was performed in 11 of 15 patients, with 15 total acquisitions. One acquisition could not be interpreted because of operator error (the incorrect acquisition protocol was selected).

Potential sites of nontarget embolization were identified in seven of 14 acquisitions (50%), or five of 11 patients (46%). These sites included the rectum (Fig 2), bladder (Fig 3), penis, seminal vesicles, and pelvic/thigh musculature (Table 2). When seminal vesicle perfusion was seen, further distal selection of the PA was performed to isolate the prostate when feasible. If other sites of potential nontarget embolization were identified, further selective angiography was performed until there was operator confidence before embolization.

In three patients (three acquisitions; 21%), prostatic parenchymal perfusion suggested the presence of duplicated PA supply (Fig 4). Perfusion was seen to the inferior/lateral capsule or superior/central gland. In seven of 14 acquisitions (50%), prostatic perfusion was

Table 2. Potential Sites of Nontarget Embolization Identified with Cone-beam CT

<table>
<thead>
<tr>
<th>Site</th>
<th>Incidence</th>
</tr>
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<tbody>
<tr>
<td>Bladder</td>
<td>2 (14)</td>
</tr>
<tr>
<td>Rectum</td>
<td>2 (14)</td>
</tr>
<tr>
<td>Penis</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Seminal vesicles</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Pelvic/thigh musculature</td>
<td>1 (7)</td>
</tr>
</tbody>
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Values in parentheses are percentages.

![Figure 4](image-url)
confirmed before embolization, with contralateral parenchymal enhancement seen in three of 14 acquisitions (three of 11 patients; 27%).

Enrollment within this prospective trial is ongoing, as is long-term clinical follow-up. Adverse event monitoring and reporting was performed per the Society of Interventional Radiology classification system. There were no major or minor complications, including urologic complications of impotence, incontinence, or prostatitis. Early clinical results demonstrated that 13 of 14 patients (93%) experienced a clinical success (ie, AUA score improvement > 3 points). There was a statistically significant improvement in AUA symptom score from baseline to 1 month (P < .0001), with a mean reduction of 13.7 (range, 6–22). Quality of life improvement was also statistically significant from baseline to 1 month, with a mean improvement of 2.1 points (P < .005).

DISCUSSION

With the anatomic complexity and small vessel size of PA anatomy, considerable challenges exist in performing PAE. The most important of these is nontarget embolization, which could potentially result in major complications and/or necessitate major surgery. Optimal treatment parameters and end-goals also remain unknown at present, including whether there is a need for bilateral embolization or treatment of duplicated PAs.

The advancement of cone-beam CT has allowed for the acquisition of a three-dimensional dataset with powerful potential clinical impact (7–11) while eliminating the need to move the patient. Cone-beam CT provides less temporal and in-plane spatial resolution than DSA, but offers exceptional soft-tissue attenuation resolution of 10 HU. Most importantly, parenchymal perfusion is well delineated on CT-like soft-tissue images.

In our experience with PAE, cone-beam CT allowed for the identification of potential sites of nontarget embolization in 36% of patients, most notably the rectum and bladder. Bilhim et al (6) noted in their experience that distinguishing the posterior lateral PA from rectal arteries is difficult because of their location and anatomic course. Sites of nontarget embolization can be difficult to visualize with DSA or may resemble prostatic anatomy, as there is superimposition of viscera in the lower pelvis and perineum. Embolization to one of these nontarget sites can carry considerable morbidity, which could be mitigated with the use of cone-beam CT.

Parenchymal perfusion can also clue the interventionalist in to the presence of duplicated PAs, which is seen in almost 50% of cases. When duplicated, the anterior lateral and posterior lateral PAs supply the more central–superior and capsular–inferior portions of the prostatic parenchyma, respectively. When cone-beam CT is performed after selection of the target PA, perfusion of the capsule or central superior gland only suggests the presence of a duplicated PA supply. Similarly, contralateral prostatic perfusion on cone-beam CT may suggest adequate embolic material distribution with unilateral embolization. We observed this in a case of unilateral PA occlusion secondary to atherosclerosis. At present, we do not know the likelihood of symptom improvement and recurrence with unilateral versus bilateral PAE.

Limitations of the present study include its retrospective nature, its lack of randomization, and the interventionist’s subjective decision to perform cone-beam CT in only 11 of 15 patients. Blinding of the operator to the findings of cone-beam CT before the decision to perform embolization would also strengthen the value of this and future studies.

In conclusion, cone-beam CT represents a useful technique that may be used during PAE. In addition to standard navigational techniques used in the angiography suite during embolization, cone-beam CT provides confirmation of the arterial vascular anatomy resulting in median lobe hyperplasia before embolization. Whereas CT angiography offers preoperative planning for PAE, cone-beam CT offers clear intraoperative benefits. Finally, this technique can potentially improve the safety of the procedure by identifying potential sites of nontarget embolization.

REFERENCES