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AJNR Am J Neuroradiol published online 30 January 2024
http://www.ajnr.org/content/early/2024/04/10/ajnr.A8171

Published April 11, 2024 as 10.3174/ajnr.A8171

Back to the Future: Dynamic Contrast-Enhanced Photon-Counting Detector CT for the Detection of Pituitary Adenoma in Cushing Disease

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ABSTRACT

SUMMARY: Historically, MR imaging has been unable to detect a pituitary adenoma in up to one-half of patients with Cushing disease. This issue is problematic because the standard-of-care treatment is surgical resection, and its success is correlated with finding the tumor on imaging. Photon-counting detector CT is a recent advancement that has multiple benefits over conventional energy-integrating detector CT. We present the use of dynamic contrast-enhanced imaging using photon-counting detector CT for the detection of pituitary adenomas in patients with Cushing disease.

ABBREVIATIONS: EID = energy-integrating detector; PCD-CT = photon-counting detector CT

MR imaging is the primary technique to evaluate pituitary lesions.[1] Postcontrast dynamic imaging of the pituitary gland has been shown to be helpful for the identification of pituitary lesions, especially small lesions.[1,2] MR imaging of the sella remains extremely challenging, predominantly due to the small size of the pituitary gland and artifacts related to the skull base and sphenoid sinus aeration patterns. Historically, MR imaging has been unable to detect a pituitary adenoma in up to one-half of patients with Cushing disease.[3] This is problematic because the identification of the adenoma is an imperative step in successful surgical resection. Photon-counting detector CT (PCD-CT) is a new technique with increased spatial and contrast resolution relative to conventional energy-integrating detector (EID) CT.[4] The purpose of this report was to describe our dynamic contrast-enhanced PCD-CT technique for the identification of pituitary microadenomas in Cushing disease.

PCD-CT Technique

A dynamic contrast-enhanced CT protocol was developed on a PCD-CT scanner (Naeotom Alpha; Siemens) for imaging patients with Cushing disease. Our institutional practice is to obtain a preoperative skull base CTA to assist surgeons with operative planning. The protocol consists of a skull base CTA scan (120-kV, CAREkeV image-quality level of 230) followed by 4 delayed scans of the sella (effective mAs of 260) spaced 20 seconds apart. All scans used a high-resolution mode with a detector collimation of 120 × 0.2 mm. The CTA scan is triggered by using contrast bolus tracking with an ROI over the ascending aorta and a trigger threshold of 175 HU at 90 kV. For the 4 scans over the sella, images were reconstructed at both 0.2- and 0.6-mm section thickness using a smooth kernel of Hr40 (with quantum iterative reconstruction strength setting of 3). Virtual monochromatic imaging at 70 keV and a low-energy threshold (T3D) were used for the 0.6- and 0.2-mm reconstructions, respectively. We performed a preliminary evaluation on multiple virtual monochromatic imaging energies, 40, 50, 60, and 70 keV, and found that the 70-keV images had the optimal balance between contrast enhancement and noise. A lower keV did increase the contrast between a microadenoma and pituitary tissue, but the increased noise degraded the image quality; 70 keV had the best visual image quality. Per our CTA protocol, the contrast dose for patients weighing <136 kg included Iohexol 350 (Omnipaque-350; GE Healthcare), 100 mL at 4 mL/s, followed by 35 mL of 0.9% NaCL at 4 mL/s. The CT dose index volume was 44.6 mGy for each delayed scan of the sella.

Cases

We present 3 patients who were diagnosed with Cushing disease after a work-up by endocrinology. These patients were defined endocrinologically as having pituitary tumors. Each patient was scheduled to undergo a preoperative skull base CTA to help guide our surgical team. The clinically indicated CTA was then augmented with 4 delayed imaging passes of the sella as described above. In all 3 patients, we identified discrete hypoenhancing lesions, compatible with a pituitary adenoma. These adenomas

Received December 11, 2023; accepted after revision January 15, 2024.

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http://dx.doi.org/10.3174/ajnr.A8171

were most conspicuous on different delayed sequences in each patient. In 2 cases, the CT-identified lesions were not seen with certainty on the comparison MR imaging.

Patient 1. A 67-year-old woman with osteoporosis, muscle weakness, and progressive weight gain was diagnosed with Cushing disease. Preoperative 1.5T MR imaging including dynamic contrast-enhanced images showed heterogeneous enhancement in the right pituitary gland without a clear lesion. PCD-CT (Fig 1) found 2 clear hypoenhancing lesions (measuring 7 and 4 mm) in the right aspect of the pituitary gland on the third dynamic series. The patient underwent transsphenoidal resection of these lesions, and pathologic examination confirmed corticotroph adenomas.

Patient 2. A 57-year-old woman who presented with uncontrolled diabetes mellitus type 2 and hypertension was diagnosed with Cushing disease. Preoperative 1.5T MR imaging demonstrated a 2- to 3-mm area of T2-hyperintense signal (Fig 2) in the left superior aspect of the pituitary gland with heterogeneous enhancement on the dynamic contrast-enhanced series. PCD-CT demonstrated a hypoenhancing lesion in the same location, best seen on the first PCD-CT series of the pituitary gland. Intraoperatively, a whitish fluid-filled lesion was seen and thought by the neurosurgical team to be consistent with a tumor, but given its liquidus consistency, it did not generate sufficient material to yield a pathologic diagnosis of corticotroph adenoma. However, biochemical remission was documented postoperatively as the patient developed postoperative adrenal insufficiency.

Patient 3. A 68-year-old man presented with osteoporotic vertebral body compression fractures, with subsequent work-up demonstrating Cushing disease. His preoperative 3T MR imaging with dynamic postcontrast imaging was severely motion-degraded and nondiagnostic. PCD-CT identified a 4-mm hypoenhancing lesion in the right aspect of the pituitary gland that involved the cavernous sinus, best seen on the fourth series (Fig 3). Intraoperatively, this imaging finding corresponded with a firm lesion that contained a pseudocapsule. Pathologic examination of the resected lesion confirmed a corticotroph adenoma.

DISCUSSION

In this report, we describe an imaging protocol for dynamic postcontrast imaging of the pituitary gland on PCD-CT. Pituitary lesions were identified on PCD-CT in 3 patients with Cushing disease.

Traditional EID-CT converts x-ray photons to visible light and subsequently converts the light to electrical signals. PCD-CT, on the other hand, simplifies this process by directly converting each photon to an electrical signal and recording its energy information. PCD-CT has shown an advantage for increased spatial resolution compared with typical clinical protocols on MR imaging and EID-CT.[5] In addition to improved spatial resolution and the potential to lower the radiation dose, PCD-CT has a higher iodine signal

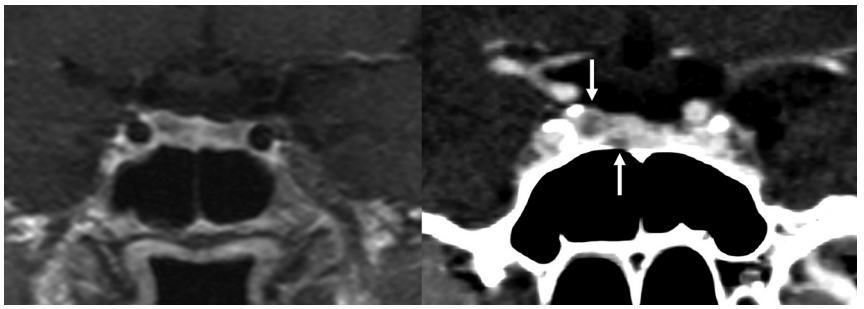

FIG 1. Patient 1, a 67-year-old woman with Cushing disease. Her preoperative dynamic postcontrast T1-weighted image (*left*) shows heterogeneous enhancement in the right pituitary gland without a definite lesion. Dynamic contrast-enhanced PCD-CT (*right*) depicting the third imaging series of the sella with 0.6-mm section thickness shows 2 distinct hypoenhancing lesions (*arrows*) in the right pituitary gland, found to be pathology-proved adenomas.

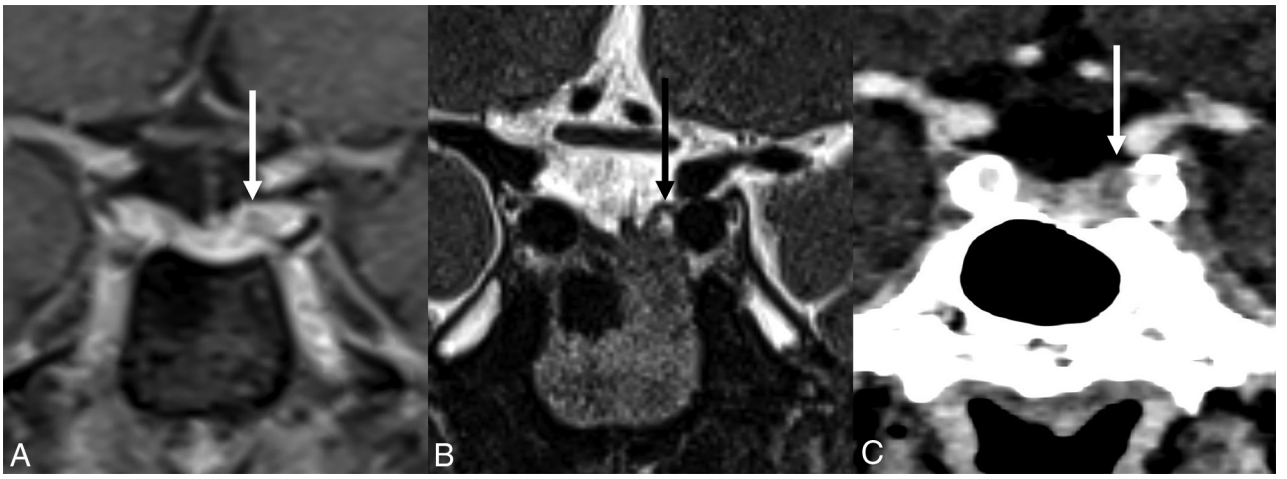

FIG 2. Patient 2, a 57-year-old woman with Cushing disease. Coronal dynamic contrast-enhanced MR imaging (*A*, *white arrow*) shows a small, hypoenhancing lesion in the left superior aspect of the pituitary gland with a corresponding T2-hyperintense signal (*B, black arrow*). PCD-CT (*C*, *white arrow*) shows corresponding hypoenhancement on the first series of the sella, seen as a coronal reconstruction at 0.6-mm section thickness.

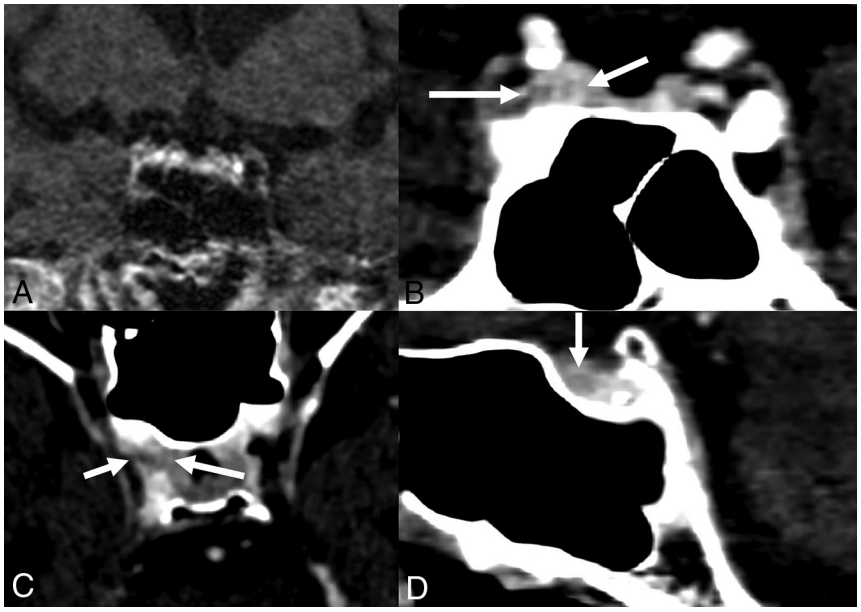

FIG 3. Patient 3, a 68-year-old man with Cushing disease. His preoperative MR imaging (*A*) was nondiagnostic secondary to motion. Coronal (*B*), axial (*C*), and sagittal (*D*) images from the fourth sequence of a dynamic contrast-enhanced PCD-CT show a hypoenhancing lesion (*arrows*) in the right aspect of the pituitary gland, which involves the cavernous sinus. This was a pathology-proved adenoma.

than EID-CT due to higher weighting of low-energy photons during photon detection, which increases the conspicuity of iodine-enhanced soft-tissue structures.[6] While it is a new application only receiving FDA approval in 2021, PCD-CT has already been shown to have multiple useful applications, including evaluation of multiple myeloma involving the spine,[7] CSF-venous fistula,[8] and temporal bone[9] among many other applications. None of these, however, have been applied to pituitary imaging.

Dynamic contrast-enhanced EID-CT imaging of the sella was previously described in the 1980s[10] and 1990s[10,11] A study published in 2015, including patients imaged beginning in 2004, found that dynamic EID-CT was more effective than MR imaging without dynamic contrast-enhanced imaging.[12] Modern imaging, however, has abandoned CT in favor of MR imaging.[1] Neuroimaging of the pituitary gland in patients with Cushing disease continues to serve an imperative function in its diagnosis and management. Cushing disease is caused by a pituitary adenoma that secretes corticotropin, subsequently leading to an increase in the production of cortisol from the adrenal cortex. Hypercortisolism leads to the development of features of overt Cushing syndrome on examination (skin fragility, bruising, striae, supraclavicular and dorsocervical pads, facial rounding, proximal myopathy); comorbidities such as hypertension, diabetes, obesity, fractures, infections, and pulmonary embolism; and an increase in mortality.[13] While inferior petrosal sinus sampling can help to distinguish Cushing disease from ectopic Cushing syndrome, it has not been shown to reliably localize a lesion within the pituitary gland.[14] This finding is particularly important because surgical resection is the standard-of-care treatment for Cushing disease. If MR imaging is unable to locate an adenoma, surgical resection is associated with a higher rate of complications and decreased cure rates.[13]

Our experience is too limited to advocate for PCD-CT as a replacement for MR imaging; however, there are several situations in which CT has advantages over MR imaging. CT tables generally have higher weight limits than MR imaging tables to accommodate larger patients, and the larger bore size of CT could help patients who cannot tolerate MR imaging due to claustrophobia. As shown in patient 3, the faster acquisition time of CT can be helpful in patients who are unable to lie still long enough for diagnostic-quality MR images to be acquired. Additionally, PCD-CT could help in patients who are unable to undergo MR imaging secondary to metal safety concerns, nonconditional implants, or gadolinium-based contrast reactions. Finally, in cases in which patients have overpneumatized sphenoid sinuses that produce problematic artifacts over the sella on MR imaging, CT image quality is not confounded by this problem. Specific to PCD-CT, the imaging technique allows thin, submillimeter section thickness. In our experience, the primary benefit of this technique is outlining the peripheral margin of the adenoma relative to the normal pituitary gland, allowing greater confidence in identifying a hypoenhancing lesion as an adenoma.

At our institution, patients scheduled for pituitary surgery undergo a preoperative skull base CTA to help with surgical planning. Thus, as is the case with all CT scans, this technique increases the radiation dose to the patient. Further work studying a larger number of patients could further refine the imaging technique to decrease the number of imaging passes of the sella and help decrease the radiation dose. Given the clear advantages of PCD-CT over EID-CT and the importance of preoperative adenoma identification in patients with Cushing disease, we believe that this technique should be thoroughly studied, and we will continue to use it as our institutional preference.

CONCLUSIONS

We provide the first description of dynamic contrast-enhanced imaging on PCD-CT for the evaluation of pituitary adenomas in Cushing disease. Given the importance of preoperative tumor localization of pituitary microadenomas to patient outcomes, this technique may potentially serve as an adjunct to cases negative on MR imaging.

ACKNOWLEDGMENTS

The authors acknowledge the support of the Mayo Clinic CT Clinical Innovation Center and Siemens Healthineers, who own the photon-counting CT used for a portion of this study under the terms of a sponsored research agreement with the Mayo Clinic.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

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