ORIGINAL ARTICLE

Comparison of Radiation Exposure and Cost Between Dynamic Computed Tomography and Sestamibi Scintigraphy for Preoperative Localization of Parathyroid Lesions

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Importance: Dynamic computed tomography (CT) is emerging as a first-line alternative to sestamibi scintigraphy for preoperative localization of parathyroid lesions. In recent years, there has been increased concern over the impact of radiation exposure from medical imaging, as well as on the cost of diagnostic medical procedures. An ideal diagnostic procedure would be cost effective while minimizing hazardous exposures and complication rates.

Objective: To compare the radiation dose and financial cost of dynamic CT with sestamibi scintigraphy.

Design, Setting, and Patients: A retrospective review of 263 patients at a large, urban, tertiary referral center who underwent either dynamic parathyroid CT or sestamibi scintigraphy for any etiology of hyperparathyroidism from 2006 through 2010.

Main Outcomes and Measures: The 2 primary study outcomes were radiation exposure measured in millisieverts (mSv) and medical charges for the respective diagnostic procedures. The study was conducted with the hypothesis that dynamic parathyroid CT would have slightly greater radiation exposure with similar cost to sestamibi scintigraphy.

Results: Dynamic parathyroid CT and sestamibi scintigraphy delivered mean radiation doses of 5.56 and 3.33 mSv, respectively ($P < .05$). Charges totaled \$1296 for thin-cut dynamic parathyroid CT and a mean of \$1112 for sestamibi scintigraphy, depending on the type and amount of radiotracer injected. Although multiphase CT scanning took less than 5 minutes, sestamibi scintigraphy lasted a mean time of 306 minutes. A total of 62 of 119 patients (52%) in the CT group have undergone operative treatment to date, whereas all patients in the sestamibi arm underwent operative treatment of their hyperparathyroidism. Of the patients who underwent a surgical procedure, CT correctly identified the side of the parathyroid adenoma in 54 of 62 patients (87%), while sestamibi scintigraphy only correctly lateralized 90 of 122 adenomas (74%) as confirmed by exploratory surgery, intraoperative parathyroid hormone levels, and pathologic features. A dynamic parathyroid CT correctly predicted multiglandular disease in 1 of 7 patients (14%), while sestamibi scintigraphy correctly predicted multiglandular disease in 8 of 23 patients (35%).

Conclusions and Relevance: In patients who underwent directed parathyroid surgery, dynamic CT is comparable to sestamibi scintigraphy in patients with hyperparathyroidism. Although CT delivers a higher dose of radiation, the average background radiation exposure in the United States is 3 mSv/y, and added exposures of less than 15 mSv are considered low risk for carcinogenesis. Overall, dynamic parathyroid CT is a safe, cost-effective alternative to sestamibi scintigraphy.

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PRIMARY HYPERPARATHYROIDism (PHPT) may be caused by a single or double adenoma, multigland hyperplasia, or parathyroid cancer. The prevalence of a single adenoma causing PHPT is 80% to 95%.[1-6] Although some centers perform bilateral neck exploratory surgery on all patients, most centers have moved toward focused parathyroidectomy with limited neck exploratory surgery. Different imaging modalities are available for preoperative localization of parathyroid adenomas, including ultrasonography, computed tomography (CT), and sestamibi–technetium Tc 99m scintigraphy. Sestamibi scintigraphy has traditionally been the preferred localizing modality; however, dynamic CT has recently emerged as a first-line alterna-

See Invited Critique at end of article

tive to sestamibi scintigraphy for preoperative localization of parathyroid adenomas. Dynamic CT has been shown to have superior sensitivity and specificity compared with sestamibi scintigraphy in identifying adenomas.[7,8] In one study, CT was found to be 85% sensitive and 94% specific for correctly lateralizing the side of the diseased gland and 66% sensitive and 89% specific for predicting the exact location of the diseased gland.[9] Sestamibi scintigraphy has a reported sensitivity range of 70% to 90% and specificity ranging between 81% and 91%.[10-15]

Recently, the impact of ionizing radiation exposure from medical studies on the risk of cancer has become a public health concern. Although the risks to any one patient are small, on a population-based level, the increased use of CTs, in particular, may result in increased cancer rates.[16] It has been estimated that 0.4% of all cancers in the United States may be attributable to the radiation from CT studies.[16] Meanwhile, the concern over the rising cost of health care in the United States is also driving the push for cost-effective medicine. Multiple studies have shown that focused parathyroidectomy with preoperative localization is a safe and cost-effective treatment for PHPT.[17,18] To our knowledge, to date, no study has compared the relative radiation exposure with the cost of different preoperative imaging modalities. The objective of this study was to compare the radiation dose and financial cost of dynamic parathyroid CT with that of sestamibi scintigraphy.

METHODS

Institutional review board approval was obtained to conduct a retrospective review of patients who underwent either thin-cut CT or sestamibi scintigraphy for any etiology of hyperparathyroidism from 2006 through 2010. At our institution, focused dynamic CT is performed from the base of the mandible to the carina, using precontrast and multiphase postcontrast imaging. Images are reconstructed with 1.25-mm slices; by comparison, conventional neck CTs are reconstructed at a thickness of 2.5 to 3 mm. Multiplanar 2-dimensional (2-D) reformatted images are generated from source images. Selected additional 2- and 3-D reconstructions are performed on postprocessing workstations. The **Figure** shows a reformatted image of a parathyroid CT.

Patients undergoing sestamibi scintigraphy received 0.28 mCi of radiolabeled iodine I 123 orally, followed by 10.2 to 20.5 mCi of radiolabeled technetium Tc 99m sestamibi intravenously. An anterior view of the neck was acquired for 10 minutes 5 to 10 minutes after injection, and again at 90 to 120 minutes after injection. All patients received a single-photon emission computed tomographic imaging of the neck and chest for anatomy. The radiation dose was obtained from radiology reports and compared in millisieverts (mSv). Electronic medical records were queried for patient age, sex, laboratory values of parathyroid hormone (PTH) and calcium levels, and operative records and pathologic features where applicable. Operative success was defined as a 50% drop in intraoperative PTH level at 10 minutes after removal of the gland and confirmation of hypercellular parathyroid by pathologic findings. Financial charges were derived from the standard Medicare payment scale and institutional fees from the billing department. Results were analyzed using a 2-tailed *t* test.

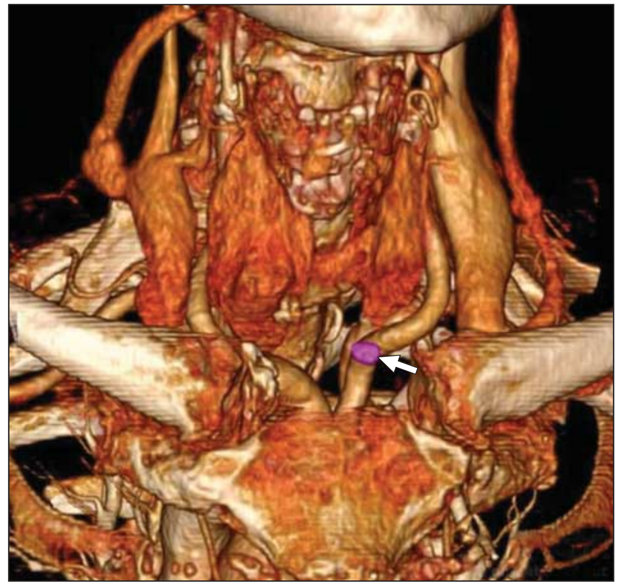

Figure. Parathyroid computed tomography showing a left inferior parathyroid adenoma (arrow).

RESULTS

A total of 119 patients underwent dynamic parathyroid CT and 144 patients underwent sestamibi scintigraphy with either single- or double-isotope injections. The mean age of the patients undergoing dynamic parathyroid CT and sestamibi scintigraphy was 60 and 58 years, respectively. Women constituted most of this study, accounting for 97 of 119 patients (81.5%) in the dynamic parathyroid CT group and 104 of 144 patients (72.2%) in the sestamibi scintigraphy group.

Dynamic parathyroid CT delivered a statistically significant higher radiation dose than sestamibi scintigraphy ($P < .05$). The mean radiation dose of dynamic parathyroid CT was 5.56 mSv, while sestamibi scintigraphy delivered a mean radiation dose of 3.33 mSv ($P < .05$). At our institution, CTs are charged according to a standard pricing scale, that is, \$1296 for dynamic parathyroid CTs. The charges for sestamibi scintigraphy are dependent on the type and amount of radiotracer injected. The mean charge for a sestamibi scan was \$1112 (range, \$669-\$1156). The duration of the localization procedure differed greatly, with all dynamic parathyroid CTs taking less than 5 minutes, while sestamibi scintigraphy took a mean time of 306 minutes (range, 50-538 minutes).

All the patients in the sestamibi scintigraphy group underwent operative treatment of their hyperparathyroidism, whereas 62 of 119 patients (52%) in the CT arm have undergone operative treatment to date. Of the patients who underwent an operation, CT correctly identified the side of the parathyroid adenoma in 54 of 62 patients (87%), while sestamibi scintigraphy only correctly lateralized 90 of 122 adenomas (74%). Computed tomography correctly predicted multiglandular disease in 1 of 7 patients (14%), while sestamibi scintigraphy correctly predicted multiglandular disease in 8 of 23 patients (35%).

COMMENT

In this study, we compared the radiation exposure and financial cost of 2 popular procedures for preoperative localization of adenomas in PHPT. We showed a statistically significant higher-radiation exposure with CT compared with sestamibi scintigraphy (5.56 mSv vs 3.33 mSv). Average background radiation in the United States is 3 mSv/y. By comparison, the average chest radiograph exposes patients to 0.1 mSv per film, while an abdominal/pelvis CT may expose patients to 15 to 30 mSv. Quantitative information on radiation-induced cancers is sparse, with all current risk estimations extrapolated from studies of survivors of the nuclear weapons dropped on Japan in 1945.[19] A cohort of approximately 25 000 survivors were exposed to low-level radiation (<50 mSv), comparable with those of CT.[20] Survivors who received low doses of radiation (5-150 mSv) showed a significant increase in the risk of cancer.[21-23] To our knowledge, no large-scale epidemiological studies about the impact of CT on cancer rates have been conducted, but based on the information gleaned from the attacks on Japan, it has been estimated that 0.4% of all the cancers in the United States may be attributable to the radiation from CT studies.[16] One recent study comparing 4-D CT with sestamibi scintigraphy found overall dosages of 10.4 and 7.8 mSv, comparatively. However, the estimated dose to the thyroid was 57 times higher than that of sestamibi scintigraphy. Based on these data, Mahajan et al[24] calculated the risk of 4-D CT-related thyroid cancer is 0.1% for a 20-year-old woman. The large difference in radiation dosage between our 2 studies (5.56 vs 10.4 mSv for dynamic parathyroid CT) highlights the fact that dynamic parathyroid CT protocols are highly specialized and may vary from institution to institution.

At our institution, dynamic parathyroid CT was on average $184 more expensive than sestamibi scintigraphy but overall, the charges were comparable ($1296 vs $1112). While a large patient volume would increase the cost disparity, it is likely that charges vary between different institutions. In addition, various studies have shown that the cost savings of improved localization offsets the increased cost of preoperative imaging and decreased operative time. In this study, we compared our institutional billing charges to either the patient or insurance organization. We did not evaluate actual reimbursements to the institution or out-of-pocket cost to the patient. It is possible that differences in reimbursement may have either narrowed or widened the gap in cost between the 2 modalities.

One of the weaknesses of this study is that only 62 of 119 patients (52%) in the CT arm had undergone surgery. Many patients who did not undergo surgery had positive localization findings on dynamic CT. Some of these patients were referred by outside physicians to our institution to receive dynamic parathyroid CT, but other patients may have returned to their local institution for surgical treatment. Other patients who were referred by physicians within our institution but who did not undergo surgery may have chosen another institution or forgone surgical management altogether. These patients are lost to follow-up. This makes it difficult to adequately compare the accuracy of dynamic CT to sestamibi scintigraphy in parathyroid adenoma localization.

Computed tomography confers the additional advantages of not requiring the patient to stop levothyroxine sodium therapy as sestamibi scintigraphy does, and it provides better anatomical detail of both the neck and chest, which can be used to identify vascular variation and nonrecurrent laryngeal nerves. Disadvantages of dynamic parathyroid CT include the potential for intravenous contrast-medium allergic adverse reactions, and the need to stop metformin therapy for 72 hours in diabetic patients. The use of dynamic parathyroid CT also requires the development of a specialized protocol and a radiologist with expertise in dynamic parathyroid CT. Considerable variation in protocols can exist from institution to institution that may affect both overall radiation exposure and cost.

In patients who underwent directed parathyroid surgery, dynamic parathyroid CT is comparable with sestamibi scintigraphy in patients with hyperparathyroidism. Although dynamic parathyroid CT delivers a higher dose of radiation, average background radiation exposure in the United States is 3 mSv/y, and added exposures of less than 15 mSv are considered low risk for carcinogenesis.

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Conflict of Interest Disclosures: None reported.

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INVITED CRITIQUE

X-rayted and Overexposed

If you are not worrying about ordering tests involving radiation exposure, your patients certainly are. This concern has been widely discussed in the press recently, and this study by Madorin et al[1] in this issue of the journal is both timely and pertinent. Although it should be incumbent on us to know the radiation exposure of a test, for the most part, we do not. A computed tomograph (CT) to identify parathyroids apparently delivers a radiation dose that is not much greater than background. My concern is the additional exposure engendered by the indiscriminate use of CT and other radiologic studies that we see all the time. The authors used a double-isotope sestamibi scan that takes more time and has no benefit over single-isotope scans and, actually, adds little additional radiation, but those of us who are not radiation physicists would not know this. If tests that involved radiation had the expected exposure listed, it would allow us to counsel patients appropriately.

Madorin et al[1] also studied the lateralizing ability of CT compared with sestamibi scanning. Unfortunately, they did not consider the use of ultrasonography that is also widely used. Although CT and ultrasonography afford much greater anatomical detail, they deliver static images, whereas, a sestamibi scan provides physiologic images albeit with less anatomical definition (the details of which can be supplemented by ultrasonography) without additional radiation exposure.

The issue of charges and cost to the patient, the institution, and the system is murky at best, but once again it raises the issue of informing the patient. I believe the cost of a test or medication and the potential radiation exposure of a radiology test should be listed as part of electronic medical record order entry so patients can be counseled intelligently. In addition, each patient's lifetime radiation exposure should, whenever possible, be a part of their medical record.

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1. Madorin CA, Owen R, Coakley B, et al. Comparison of radiation exposure and cost between dynamic computed tomography and sestamibi scintigraphy for preoperative localization of parathyroid lesions [published online April 10, 2013]. *JAMA Surg*. 2013;148(6):500-503.