Original Article

Four-dimensional computed tomography and ultrasonography for prediction of pathological parathyroid location: a retrospective review of a single surgeon's patients at a single institution

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Background: Pre-operative imaging is a well-established practice for managing hyperparathyroidism with the plan for excision; however, there is a paucity of information regarding the success rate of concordant imaging studies. Our goal was to compare the accuracy (sensitivity) of four-dimensional computed tomography (4DCT) and ultrasound (US) when predicting the side and quadrant of parathyroid lesions, confirmed with surgical location (from a single surgeon).

Methods: A retrospective review of 437 patients from a single surgeon undergoing parathyroidectomy from December 2013 to January 2020 at an academic medical center was performed. Masses >5 mm in dimension in eutopic parathyroid locations were identified as possible parathyroid lesions on 4DCT. A unique codified system was utilized to accurately record imaging results for each modality and compared to surgical findings.

Results: Four hundred and thirty-seven patients underwent parathyroid surgery, of those 431 underwent 4DCT, 413 underwent US, and 408 underwent both. 4DCT accurately lateralized lesions in 319 (74.0%; N=431). US lateralized lesions in 265 (64.2%; N=413). The sensitivity for lateralization was 81.2% and 69.9% for 4DCT and US, respectively.

Conclusions: 4DCT and US identify the majority of parathyroid lesions. 4DCT outperformed US in lateralization yet both modalities remain useful and are complimentary in planning for successful parathyroidectomy. Newer imaging approaches such as ^{18}F-choline positron emission tomography/computed tomography (PET/CT) and artificial intelligence as an augmentation to imaging review may play in role to identify parathyroid adenomas/hyperplasia, but their roles have yet to be clearly defined.

Keywords: Four-dimensional computed tomography (4DCT); ultrasound (US); preoperative imaging; parathyroid; hyperparathyroidism

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Introduction

Background

Preoperative imaging for localization of parathyroid adenomas/hyperplasia is a well-established practice which has facilitated the advent of focused surgery including minimally invasive and remote access parathyroid procedures. While imaging is an asset for surgical planning, it should not be used to make the diagnosis of primary hyperparathyroidism (pHPT) or a decision of whether to operate. Imaging modalities vary due to surgeon preference, local resources, and expertise (1). The objective of this project was to describe the experiences of one surgeon at a single institution; to highlight the roles that ultrasound (US) and four-dimensional computed tomography (4DCT) play in pre-operatively identifying parathyroid lesions that guide minimally invasive surgery; and to review the literature to address new imaging modalities and their role in treating pHPT.

The American Head and Neck Society Endocrine Surgery Section recommends that high-definition neck US by an experienced sonographer should be supplemented with either planar sestamibi with single-photon emission computed tomography (SPECT) or SPECT-CT, multiphase computed tomography (CT), or magnetic resonance imaging (MRI) for preoperative parathyroid surgery planning (2). At our institution, we have preferred the use of both preoperative (in clinic) US and 4DCT scans as our routine for planning parathyroid surgery (3). Recently other imaging modalities have been utilized in primary non-localizing or revision parathyroid surgery cases such as ^{18}F-choline positron emission tomography (PET) (4-7).

Highlight box

Key findings

- Four-dimensional computed tomography (4DCT) more accurately predicts parathyroid adenoma location than in-office ultrasound. When they are in agreement, there is a high likelihood that the identified location is correct.

What is known and what is new?

- Pre-operative imaging allows for more successful minimally invasive parathyroidectomy.
- 4DCT is more accurate than in-office ultrasound.
- New imaging modalities may change the imperative for multi-modality imaging studies.

What is the implication, and what should change now?

- Those using single modality imaging techniques prior to parathyroidectomy should consider 4DCT; however, we would like to emphasize the improved success of multi-modality imaging.

Rational and knowledge gap

Sonography is the most common first-line imaging modality for parathyroid localization due to its accessibility, safety, and low cost (4). Advantages of sonography include: it does not require the patient to lie supine for an extended time, post-imaging processing, intravenous (IV) contrast; and the equipment is readily available. The portability of an US and lower threshold to use makes this the most effective imaging modality in a patient presenting with hypercalcemia to determine if a suspicious parathyroid lesion exists (8). Significant limitations of preoperative US imaging include difficulty in identifying small parathyroid glands, hyperplasia, ectopic, or intrathyroidal parathyroid glands, inability to easily determine if parathyroids are hyperactive, difficulty in differentiating lesions from synchronous nodular thyroid disease, and increased difficulty in scanning a large body habitus (4). US is the ideal first line study but may not be the definitive study for many patients. Further imaging to achieve concordant imaging or initial localization may be necessary (9).

Compared to US and SPECT-CT, 4DCT scan is a newer imaging approach for preoperative parathyroid localization (4). 4DCT has multi-planar capability: axial acquisition and displays with coronal and sagittal reconstruction, along with the possibility of examining oblique planes. The fourth dimension in 4DCT is a change in tissue contrast enhancement over time: non-contrast enhanced (time 0), arterial phase (30 seconds following contrast infusion), and delayed venous phase (90 seconds) are compared (10). Several series in the literature have demonstrated that 4DCT scan sensitivity is superior to US and SPECT/CT (3,11,12). Furthermore, 4DCT has been shown to be useful in cases where prior imaging results were negative or inconclusive, and where patients required revision parathyroid surgery (13,14). The major limitations of 4DCT scans include concerns regarding radiation exposure and artifacts related to intravascular contrast that could obscure or spuriously alter the apparent density of potential candidate parathyroid lesions and thereby complicate pathologic gland identification (4).

In one meta-analysis of preoperative imaging for patients with pHPT, Cheung found that US had a pooled sensitivity of 76.1% and positive predictive value (PPV) of 93.2% while 4DCT had a pooled sensitivity of 89.4% and PPV of

93.5% (15).

Objective

We designed this report to analyze our own institution's data on preoperative imaging of 4DCT and US in detecting the preoperative location of parathyroid gland(s) associated with hyperparathyroidism to highlight the utility of these imaging modalities when planning minimally invasive parathyroid surgery. A limited review of current literature was also performed to include information regarding choline PET/CT technology and its emerging role in the treatment of hyperparathyroidism. We present this article in accordance with the STARD reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-24-141/rc).

Methods

Patient selection

All research was conducted at a single academic hospital, University of Arkansas for Medical Sciences (UAMS). Ethics approval was obtained and the requirement for informed consent was waived by the UAMS Institutional Review Board (IRB #205694). Informed consent was not required from the patients as all information was de-identified at the time of tabulation and statistical analysis. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Electronic medical records were queried for patients undergoing parathyroid surgery by a single surgeon (B.C.S.) for any indication between December 2013 (when we adopted routine 4DCT use) and January 2020 (6 years, 2 months) (3). A retrospective chart review was performed of all eligible patients with the following data extracted: demographics; preoperative images (4DCT scan and US) and identified parathyroid location(s); parathyroid size on image; final pathology (single adenoma, double adenoma, hyperplasia, or parathyroid carcinoma); pathology measured gland dimensions and mass; and reported parathyroid surgical location(s) based on operative note. The anatomical markers used to define quadrants during the procedure were ZukerKandl's tubercle and the position of the recurrent laryngeal nerve, and the relation of the identified gland (superior, inferior, deep, or superficial) to these landmarks. Laboratory values were collected for all patients. Biochemical resolution was determined by a blood calcium level <10.4 mg/dL and a parathyroid hormone (PTH) level <88 pg/mL. These values were determined based on the upper limit of normal for our institution's reference lab (16).

Imaging was done preoperatively and determined to be correct by pathology confirmation after surgical removal of the suspect glands and achievement of post-operative biochemical resolution of hypercalcemia/elevated PTH. An imaging modality was considered correct only if it precisely identified and localized all parathyroid abnormalities confirmed by surgical and pathologic findings.

Ninety-two percent of patients (402/437) underwent a focused parathyroid surgery (17). Bilateral exploration was planned in advance and performed in the instance that a patient had an a priori double adenoma with lesions located bilaterally or hyperplasia. Bilateral exploration was also performed in cases where intraoperative biochemical resolution was not achieved after unilateral exploration with initial excision of the suspect lesion(s) on the image-indicated side (see below).

Imaging protocol

All patients undergoing surgery for pHPT received an office US and a preoperative 4DCT (10). Most patients with severe renal disease, not dialysis-dependent, did not receive a preoperative 4DCT scan. In cases where the surgery was scheduled promptly after an inpatient consult, these patients did not receive the customary preoperative US. Consequently, such cases were excluded from our reported experience.

Image interpretation

All parathyroid US were performed by one Head and Neck endocrinologist (D.L.B.). 4DCT scan interpretation utilized a parathyroid protocol at our institution, instituted by R.F., and required the radiologist to identify any mass over 5 mm in an eutopic parathyroid location (18) who were otherwise blinded to clinical data. All 4DCT images were interpreted by fellowship trained Head and Neck radiologists, reviewed preoperatively by the surgeon (B.C.S.), and projected on a large screen in the or during surgery.

Surgical treatment

Most patients were brought to the operating room (OR) following dual modality imaging with the intent to do a focused parathyroid excision. Surgery most often consisted

Table 1 Descriptive statistics of the study population (n=437)

Descriptive statistic	Value
Average age at surgery (years)	64.1
Gender, n (%)	
Male	89 (20.4)
Female	348 (79.6)
Diagnosis, n (%)	
Primary hyperparathyroidism	419 (95.9)
Double adenoma	70 (16.0)
Secondary hyperparathyroidism	7 (1.6)
Tertiary hyperparathyroidism	5 (1.1)
Parathyroid carcinoma	2 (0.5)
Surgery, n (%)	
Focused	402 (92.0)
Bilateral exploration	35 (8.0)

of a unilateral neck exploration identifying the superior and inferior parathyroid glands and recurrent laryngeal nerve on the side indicated by the preoperative studies (92% of cases, *Table 1*). In cases with discordant imaging or no localization, neck exploration started on the side most suggested to harbor the hyperfunctioning parathyroid(s) or side with least thyroid nodular pathology.

Once a side had been explored and abnormal gland(s) excised, a ten-minute post excision intraoperative PTH (IOPTH) was measured and compared to the preoperative baseline, subjected to modified Miami criteria (>50% reduction and return to within normal range (12–88 pg/mL). If the IOPTH drop met criteria, exploration was terminated. If the IOPTH did not drop sufficiently to meet the criteria above, and a suspicious parathyroid lesion had been excised, a second IOPTH sample was obtained. If this result also failed to demonstrate an adequate resolution of the hyperparathyroidism or a suspicious parathyroid(s) had not been excised, the contralateral side was explored as described above, additional IOPTH(s) was (were) obtained, and the operation was concluded.

Data collection and statistical analysis

Data was tabulated by a member of the department of biostatistics (H.J.S.) and distributed onto a grid displaying: (I) where the imaging modality predicted the adenoma to be present; (II) where the adenoma was found during surgical exploration and confirmed by pathology. For the laterality of the lesion, a two-digit code was formulated for the imaging modality and surgery in the form of d_1d_2, where d_1 represents the left-sided results and d_2 the right-side result. Each d can then be treated as 0 (no) or 1 (yes). Similarly, for neck quadrants, a four-digit codes of the form $d_1d_2d_3d_4$ are presented where d_1 is the left superior quadrant, d_2 is the left inferior quadrant, d_3 is the right superior quadrant, and d_4 is the right inferior quadrant result. Tables of this unique methodology of analysis of parathyroid data is found in the supplement (https://cdn.amegroups.cn/static/public/GS-24-141-Appendix 1.xlsx).

Matches were defined as the pattern for the imaging modality which exactly matched the pattern identified from surgery (https://cdn.amegroups.cn/static/public/GS-24-141-Appendix 1.xlsx). The surgical findings were treated as the gold standard when used to determine the measure of each imaging modality for both lateralization and quadrant localization. Analysis was performed using SPSS Statistics Premium v24.0 (IBM Corp., NY, USA).

Results

The 437 patients in this study were predominantly females (348, 79.6%) with an average age of 64.1 years (*Table 1*). The majority of the patients were diagnosed with pHPT (97.2%). Secondary and tertiary hyperparathyroidism were diagnosed in 7 and 5 patients, constituting 1.6% and 1.1% of the study population, respectively. Other notable parathyroid variations included double adenomas and parathyroid carcinoma identified in 70 (16.0%) and 2 (0.5%) patients respectively.

Four hundred and thirty-seven underwent surgery, 431 had pre-operative 4DCT scans, 413 underwent pre-operative US. Four hundred and eight patients underwent both 4DCT and US preoperatively, followed by surgery. 4DCT lateralized the parathyroid adenomas to the correct side in 272 (63.1%) cases and localized the lesion to the correct quadrant in 205 (47.6%) cases. In comparison, US correctly lateralized in 211 (51.1%) patients, and correctly localized in 143 (34.6%) patients.

When analyzing the value of each modality for correct laterality and quadrant, the sensitivities of 4DCT and US were 69.21% and 55.67% for laterality and 52.16% and 37.73% for quadrant localization respectively (*Table 2*). Positive and negative predictive values for each location per modality are listed in *Tables 3-6*. Localization to a

Table 2 Summary statistics for 4DCT and ultrasound

Imaging modality	Correct localization of lesion, n (%)	Sensitivity for localization, %	Correct lateralization of lesion, n (%)	Sensitivity for lateralization, %
4DCT (n=431)	205 (47.6)	52.16	272 (63.1)	69.21
Ultrasound (n=413)	143 (34.6)	37.73	211 (51.1)	55.67

4DCT, four-dimensional computed tomography.

Table 3 Screening statistics for lateralization of lesion to each side using 4DCT

Screening evaluation	Left (n=431)	Right (n=431)
Accuracy	80.9 (76.9–84.5)	80.3 (76.2–83.9)
Sensitivity	79.2 (73.3–84.5)	76.2 (70.2–81.4)
Specificity	82.7 (77.0–87.5)	85.4 (79.6–90.1)
PPV	82.3 (77.0–87.5)	86.7 (81.3–91.0)
NPV	78.0 (73.8–84.8)	74.2 (67.9–79.8)

Data are presented as % (95% CI). 4DCT, four-dimensional computed tomography; NPV, negative predictive value; PPV, positive predictive value; CI, confidence interval.

Table 4 Screening statistics for lateralization of lesion to each side using ultrasound

Screening evaluation	Left (n=413)	Right (n=413)
Accuracy	72.1 (67.5–76.4)	71.4 (66.7–74.7)
Sensitivity	61.8 (54.9–68.5)	65.4 (58.9–71.5)
Specificity	82.4 (76.5–87.4)	79.0 (72.3–84.7)
PPV	78.0 (70.9–84.1)	79.9 (73.5–85.4)
NPV	68.1 (62.0–73.9)	64.1 (57.5–70.4)

Data are presented as % (95% CI). NPV, negative predictive value; PPV, positive predictive value; CI, confidence interval.

Table 5 Screening statistics for localization of lesion to each side and ectopic locations using 4DCT

Screening evaluation	Left superior	Left inferior	Right superior	Right inferior	Ectopic
Accuracy	81.6 (77.7–85.2)	80.7 (76.7–84.4)	83.2 (79.4–86.7)	79.5 (75.5–83.3)	85.4 (81.7–88.6)
Sensitivity	61.4 (52.7–69.7)	68.7 (58.6–77.6)	57.3 (47.8–66.4)	68.1 (59.7–75.8)	40 (27.0–54.1)
Specificity	90.9 (87.0–93.9)	84.3 (80.0–88.0)	93 (89.6–95.6)	85 (80.4–88.9)	92.0 (88.8–94.6)
PPV	75.4 (66.3–83.2)	56.7 (47.3–65.7)	75.3 (65.0–83.8)	68.1 (59.7–76.0)	42.3 (28.7–56.8)
NPV	83.8 (79.3–87.7)	90 (86.2–93.1)	85.4 (81.2–89.0)	85 (80.4–88.9)	91.3 (88.0–93.9)

Data are presented as % (95% CI). 4DCT, four-dimensional computed tomography; NPV, negative predictive value; PPV, positive predictive value; CI, confidence interval.

Table 6 Screening statistics for localization of lesion to each side and ectopic locations using ultrasound

Screening evaluation	Left superior	Left inferior	Right superior	Right inferior	Ectopic
Accuracy	74.0 (69.5–78.2)	75.2 (70.8–79.3)	75 (70.5–79.1)	73.5 (69.0–77.7)	86.5 (82.8–89.7)
Sensitivity	25.2 (17.9–33.7)	61.1 (50.5–70.9)	29.7 (21.4–39.2)	59.0 (50.1–67.4)	6.0 (1.3–16.6)
Specificity	95.8 (92.8–97.8)	79.5 (74.6–83.8)	91.7 (88.0–94.6)	80.6 (75.4–85.1)	97.8 (95.6–99.0)
PPV	72.7 (57.2–85.0)	47.2 (38.1–56.4)	56.9 (43.2–69.8)	59.4 (50.5–67.8)	27.3 (6.0–61.0)
NPV	74.2 (69.4–78.6)	87.2 (82.7–90.8)	78.0 (73.3–82.2)	80.3 (75.1–84.8)	88.2 (84.6–91.2)

Data are presented as % (95% CI). NPV, negative predictive value; PPV, positive predictive value; CI, confidence interval.

Table 7 Statistical analysis of patients with single-gland disease (n=361)

Statistic	Laterality concordant	Quadrant concordant
n	184	132
Accuracy by pathology, n (%)	153 (83.2)	97 (73.5)
PPV	0.981	0.843

PPV, positive predictive value.

side is a functional requirement for image guided focused exploration whereas localization to quadrant is the most stringent, and perhaps unduly rigorous standard for localization without practical application.

A small portion of our patients were found to have ectopic parathyroid glands. A total of 53 ectopic glands were identified at surgery whereas 4DCT and US identified 44 and 10 glands respectively. Thirteen of the ectopic parathyroid glands were identified within the thyroid gland. When detected by imaging the accuracy of identifying the ectopic gland was 86.5% (*Table 6*).

Further subgroup analysis of 361 patients with single parathyroid lesions on pathology was performed. Of those, accuracies and PPVs were determined for concordance. This included 184 patients with both 4DCT and US findings of a single adenoma on the same side, 153 (83.2%) patients had adenomas on the predicted side. Of the 132 patients with 4DCT and US concordant to the same quadrant, 97 (73.5%) patients had adenomas in the predicted quadrant. PPVs for concordant laterality and quadrant are 0.981 and 0.843, respectively (*Table 7*). These statistics are more compatible with ones previously reported (19).

Discussion

US identification of parathyroid adenomas, while a proven and practical option, has limitations that make the use of advanced imaging modalities a necessity in the preoperative algorithm for surgery upon dysfunctional parathyroids (3). US remains a key modality in the preoperative work up due to its accessibility, low cost, and general utility in identification of parathyroid adenoma(s) (2). The advent and adoption of other imaging modalities has increased the accuracy of preoperative localization, especially when used in combination with US (11). The paradigm of parathyroid surgery has moved from universal non-image guided four-gland exploration to a focused/minimally invasive approach providing improved cosmesis as well as reduced operative times, manipulation of the recurrent laryngeal nerves/normal parathyroids, and costs (18). This may continue to evolve with the introduction of percutaneous ablative technology (20).

In the experience of a single parathyroid surgeon (B.C.S.), biochemical evidence of cure was achieved in the majority (95%) of patients routinely observed for one year. Cure was defined by the maintenance of normal calcium levels for >6 months post-operatively and is achieved in 95% of patients that are treated by experienced surgeons (16,21). Forty patients (9.28%) achieved normocalcemia despite persistent elevated PTH at their first postoperative visit consistent with findings from previous studies (22-24). Normocalcemia was achieved in spite of our routine of post parathyroidectomy supplemental (prophylactic) oral calcium use (25).

This study constitutes one of the largest cohorts of 4DCTs used in preoperative parathyroid imaging performed at single institution by a single surgeon. The findings indicate that US remains a key tool of parathyroid imaging. This modality correctly identifies many of the parathyroid adenomas excised in this study. However, consistent with published guidelines, all patients at our institution undergo dual modality screening by the addition of 4DCT in preparation for surgery (2). Our findings substantiate the advantage of concordant imaging and, that with the two modalities, parathyroid adenomas are correctly localized, allowing for 92% of patients to undergo unilateral focused, minimally invasive surgery.

Correct identification of the laterality of parathyroid adenomas plays an important role in operative planning for a focused procedure. With parathyroid adenoma laterality, a surgeon can perform focused surgery with a small incision compared to a standard 6 cm Kocher incision. This obviates universal bilateral four-gland exploration utilized prior to the development of contemporary high-fidelity parathyroid imaging. Our results indicate that both US and 4DCT represent robust options for parathyroid lateralization. Our study found that when imaging modalities are concordant to the same side, they accurately localize the adenoma in 98% of patients.

In an analysis of single-gland disease patients, several statistical findings were not able to be reported due to the design of our study. Sensitivity, specificity, and negative predictive value all involve utilization of the false negative rate of a population. The manner in which two imaging modalities were recorded, there are multiple ways in which the test can be incorrect, but only one way in which the test can be correct. This would lead to spuriously elevated false negative and true negative numbers and could drastically skew the final statistical analysis. Furthermore, the fact that all patients did not undergo bilateral exploration further contributed to this limitation. Therefore, those values were excluded from our reporting.

Comparison of the localizing (quadrant) value of US and 4DCT in our study corroborates the findings of previous studies in that 4DCT was superior to US at localizing parathyroid adenomas (11,15,26). Differences between this study and previous studies include the large sample size of 4DCTs done at a single institution. As noted by Bahl, the use of 4DCT has been increasing in recent years with good results (11). The early date of adoption of this modality at our institution combined with a busy parathyroid practice has allowed for a large study population compared to previous studies. It is possible that early adoption also affected the initial accuracy of 4DCT reads as radiologists have become more facile with performing and interpreting this exam.

Further consideration should be given in future studies to noting instances when the image reader described suspected lesions that were near the plane of the thyroid isthmus. This occurred in instances indicating an equivocal exam with respect to quadrant, but not effecting laterality. Superior *vs.* inferior gland is determined intraoperatively by the gland's location with respect to the planes of recurrent laryngeal nerve or ZukerKandl's tubercle, making it difficult to accurately classify up/down via imaging modalities where these structures are not appreciated (4,27). These factors may account for discrepancies seen in the quadrant localizing value of our data compared to the cited studies. There may be limited clinical need in reporting quadrant localization in patients undergoing focused, unilateral surgery. It is our practice to explore the superior and inferior poles of the thyroid when performing unilateral surgery due to the known variable anatomic positioning of the parathyroids and to compare glands.

This study may be further limited by the radiology guidelines utilized at our institution which recommend identifying all lesions on 4DCT that were greater than 5 mm and in a eutopic parathyroid location as a potential parathyroid; this would obviously increase the possibility of false positive reporting (lymph nodes) and lower the overall sensitivity (small/ectopic parathyroids) of the modality. Based on analysis of our patient population, using a cutoff of 5 mm is likely an appropriate cutoff. Only six lesions were found to be smaller than this cutoff (4 by 4DCT, 2 by US). Comparing the results to a previously published small cohort study at our institution, this guideline and additions to the pool of reading radiologists over time could have caused a decrease in the sensitivity of 4DCT (3).

Since the incidental discovery of ^{18}F-choline PET/CT's utility in identifying hyperfunction parathyroid(s) in 2013, there has been investigation into this modalities accuracy and how it compares to other forms of imaging. It was initially supported for use in combination with 4DCT imaging for identifying parathyroid adenomas in patients with negative findings upon initial imaging (5,7). This modality has been found to be most impactful in identifying lesions in patients requiring parathyroid re-operation surgery (28). Further studies have been valuable in determining ^{18}F-choline or ^{11}C-choline PET/CT's role in initial imaging of patients with hyperparathyroidism (19). In a 2024 comparison of ^{18}F-choline PET/CT to ^{99m}Tc-sestamibi SPECT/CT, there was strong support of better detection rates with the new technology (90.3% *vs.* 57%) (7). As this new form of imaging becomes more widely accepted/available, its role in pre-operative workup of parathyroid nodules will become better defined.

Advancements in the technology outside of imaging have been mentioned in the literature as adjuncts to improve pre-operative detection. Artificial intelligence, with its growing role in data analysis, is undergoing early studies to using patient specific information such a laboratory values to identify patients with primary hyperthyroid prior to imaging (29). Additional studies are using machine learning to review images of patients with hyperparathyroidism to form accurate models for identifying and stratifying those with multiglandular disease (30). Artificial intelligence, while still in development for use in endocrine surgery, already shows promise in efficiency of workup and early identification of patients at risk for hyperparathyroidism.

Use of a single, experienced head and neck sonographer increased the precision of US imaging as compared to other reports in the literature (13,29,31). The role of US allows for a convenient first-line test that can be performed at the initial visit to confirm early suspicions for parathyroid disease (2,11,16). Certain studies have described this as the most variable and least sensitive of imaging modality, however it is largely dependent on the skill of the operator (26). The US and 4DCT combination performed best in cases of single adenoma pHPT. The possibility exists of a future study to expand on the role of 4DCT in identifying and describing co-existing thyroid nodules similar to a previous small cohort study at our institution (32,33).

Conclusions

Our data suggest that preoperative 4DCT had superior agreement with surgical location of parathyroid abnormalities compared to office US. Concordant imaging further increased the likelihood of accurate preoperative localization of parathyroid lesions. Single gland cases had the best imaging outcome. Future work remains to determine the effects of imaging guidelines, image reader confidence, novel imaging technology, and machine learning on pHPT detection sensitivity and accuracy.

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Footnote

Reporting Checklist: The authors have completed the STARD reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-24-141/rc

Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-24-141/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-24-141/coif). R.F. reports that since 2017, he has been employed as a physician by Radiology Consultants of Little Rock. Radiology Consultants and his work with the group have no relationship, financial or otherwise, to this manuscript. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Ethics approval was obtained and the requirement for informed consent was waived by the UAMS Institutional Review Board (IRB #205694). Informed consent was not required from the patients as all information was de-identified at the time of tabulation and statistical analysis. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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