Surgery xxx (2025) 109706

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

Use of a Best Practice Advisory to increase the detection rate of hyperparathyroidism

Rebecca S. Gates, MD, MMHPE[a,*], Kristin McCoy, MD[a], Jonathan Stewart, MD, FAAFP[b], Andrew J. Behnke, MD[c,d], Adegbenga Bankole, MD[d], Theresa Vallia, BA[e], Michael S. Nussbaum, MD, FACS, MAMSE[a], Daniel Tershak, MD[a]

[a] Department of Surgery, Carilion Clinic - Virginia Tech Carilion Clinic School of Medicine, Roanoke, VA
[b] Department of Family and Community Medicine, Carilion Clinic - Virginia Tech Carilion Clinic School of Medicine, Roanoke, VA
[c] Section of Endocrinology, Department of Internal Medicine, Carilion Clinic - Virginia Tech Carilion Clinic School of Medicine, Roanoke, VA
[d] Department of Internal Medicine, Carilion Clinic - Virginia Tech Carilion Clinic School of Medicine, Roanoke, VA
[e] Health Analytics Research Team, Carilion Clinic, Roanoke, VA

ARTICLE INFO

Article history:
Accepted 3 June 2025
Available online xxx

ABSTRACT

Background: Timely diagnosis and treatment of primary hyperparathyroidism requires a high index of suspicion and collaboration across specialties. The diagnosis often is overlooked. This study aimed to determine whether the introduction of a screening algorithm for primary hyperparathyroidism would increase diagnosis and treatment rates.
Methods: An electronic health record Best Practice Advisory was launched in 2022, encouraging parathyroid hormone testing for patients with hypercalcemia (calcium ≥11 mg/dL). Parathyroid hormone testing, specialist referrals, and parathyroidectomy were examined pre- and postintervention.
Results: There were 902 and 893 patients with hypercalcemia in the pre- and postintervention groups, respectively. Parathyroid hormone testing increased from 24.61% to 38.75% after the Best Practice Advisory was implemented ($P < .01$). Specialist referrals and rates of parathyroidectomy were unchanged between the pre- and postintervention groups (referrals in 41.44% vs 41.04% of those with parathyroid hormone testing, $P = .93$; parathyroidectomy in 27.17% vs 26.76% of those referred, $P = 1.00$). Parathyroid hormone testing was performed more commonly in older patients (69.63 vs 59.01 years, $P < .01$). Patients referred to a specialist were younger (67.59 vs 71.05 years, $P = .04$). Patients with primary hyperparathyroidism–associated comorbidities were more likely to undergo parathyroid hormone testing, with no differences in rates of specialist referrals ($P = .11$) or parathyroidectomy ($P = .60$).
Conclusion: An electronic health record Best Practice Advisory was effective in increasing primary hyperparathyroidism screening, but did not result in a higher rate of specialist referrals or parathyroidectomies. Reflex parathyroid hormone testing as well as increased education about primary hyperparathyroidism may further improve screening, referrals, and treatment.

Introduction

Primary hyperparathyroidism (PHPT) is the third most-common endocrine disorder after diabetes and thyroid disease.[1] Its prevalence in the United States is estimated at 233 and 85 per 100,000 women and men, respectively, although this number is influenced by screening algorithms.[2] Untreated PHPT may contribute to renal disease (usually in the form of kidney stones), osteopenia/osteoporosis and pathologic fractures, decreased quality of life, and potentially even metabolic syndrome (insulin resistance, cardiovascular disease, obesity).[3–6]

Once diagnosed, PHPT can be biochemically cured in 95–99% of cases by parathyroidectomy.[7] After parathyroidectomy, renal stones and bone mineral density usually improve, and many patients endorse an improvement in quality of life.[3,5,8–10] Although timely diagnosis and treatment may yield significant health benefits for affected patients, the symptoms of PHPT are commonly

Presented at the 45th Annual Meeting of the American Association of Endocrine Surgeons, May 17–19, 2025, Milwaukee, WI.
* Corresponding author: Rebecca S. Gates, MD, MMHPE, Department of Surgery, Carilion Clinic – Virginia Tech Carilion School of Medicine, 1906 Belleview Avenue SE, Roanoke, VA 24014.
E-mail address: rsgates@carilionclinic.org (R.S. Gates).

https://doi.org/10.1016/j.surg.2025.109706
0039-6060/

vague and nonspecific, and this often leads to a delayed or missed diagnosis. Previous studies have demonstrated that only approximately one third of patients with hypercalcemia receive further investigation with parathyroid hormone (PTH) levels,[11] and of these, less than one quarter are referred to surgeons for consideration of parathyroidectomy.[12] These trends are mirrored in our hospital system, with only 24% of patients with hypercalcemia receiving further workup.

Improvement in PHPT detection may lead to increased cute rate and fewer patients facing negative manifestations of the disease. Best Practice Advisory (BPA) alerts within the electronic health record (EHR) have shown promise in systems-based efforts to guide clinician decision-making and improve detection rates for various conditions.[13,14] As such, we implemented a BPA in our health system, prompting clinicians to order a PTH level when hypercalcemia (a single level of hypercalcemia ≥11 mg/dL) was detected on routine laboratory studies. In this study, we aimed to investigate the impact of that BPA on PHPT screening, detection, and treatment.

Methods

Design and implementation

In 2022, rates of PTH testing after demonstration of hypercalcemia were evaluated internally at our institution. Similar to national trends,[11] these testing rates were noted to be very low (<25%), and, as such, a BPA was created to remind clinicians to order PTH testing for patients with hypercalcemia and 1 serum calcium measurement greater than or equal to 11 mg/dL. This number was chosen by consensus because it was greater than 3 standard deviations outside of the population mean of serum calcium, was an easy number for clinicians to recognize, and reduced the rates of false-positive hypercalcemia from a single laboratory test draw.[15] The upper limit of normal serum calcium at our institution is 10.7 mg/dL. After creation and review by a team of experts at our institution, the BPA went live in November 2022. Whenever a clinician in an ambulatory setting entered the chart of a patient with a recent outpatient laboratory study showing a calcium greater than or equal to 11 mg/dL, the BPA flagged and prompted them to consider ordering a test for PTH level (Figure 1). Subsequent PTH testing, endocrinology or surgery referrals, and parathyroidectomy were evaluated pre- and post-BPA to gauge its efficacy.

Data collection and statistical analysis

Data were gathered for a 6-month period preintervention and a 6-month period postintervention, with a washout period in between. The preintervention group was made up of patients who had new hypercalcemia (serum calcium ≥11 mg/dL) noted on laboratory studies between 1 January 2021 and 1 July 2021. The postintervention group was made up of similar patients between 1 January 2023 and 1 July 2023. Demographic variables including age, sex, race, and comorbidities were collected for each patient. Comorbidities included nephrolithiasis, chronic kidney disease, osteopenia or osteoporosis, diabetes or prediabetes, hypertension, hyperlipidemia, obesity, anxiety or depression, and vitamin D deficiency. These were identified by *International Classification of Diseases*, *Tenth Revision*, codes (Supplementary Table S1). Included patients were retrospectively examined for PTH testing, referral to endocrinology or a surgical specialist, and completion of parathyroidectomy at our institution over the 365 days after their first elevated calcium test. The window of 365 days was chosen by author consensus because it was thought to represent a reasonable amount of time for progression through the algorithm of HPT diagnosis and potential treatment. Due to chart review and precharting practices at our institution, the PTH testing outcome was defined as any PTH test that occurred within 365 days and was not confined to testing that was ordered directly though the BPA. For the purposes of data stratification, PTH results were separated into 3 groups: PTH <40 pg/mL, PTH 41–65 pg/mL, and PTH >65 pg/mL. Referrals to general surgery, surgical oncology, endocrine surgery, vascular surgery, or head and neck surgery were all included in the "referral to surgical specialist" group, because these surgeons all routinely perform parathyroidectomies at our institution. Parathyroidectomy was defined as Current Procedural Terminology codes 60500, 60502, or 60505. Data were collected retrospectively through TriNetX and Epic.

Demographic variables were compared between the pre- and postintervention groups. The proportion of patients receiving PTH testing, referrals to endocrinology or a surgical specialist, and surgical intervention (parathyroidectomy) also were compared. Lastly, the postintervention group was examined for differences in rates of PTH testing, referrals, and parathyroid operations on the basis of calcium levels and demographic variables. *T*-tests (age) as well as Fisher exact tests were used for all analyses, which were performed in SAS Studio (SAS Studio 5.2; SAS Institute Inc, Cary, NC).

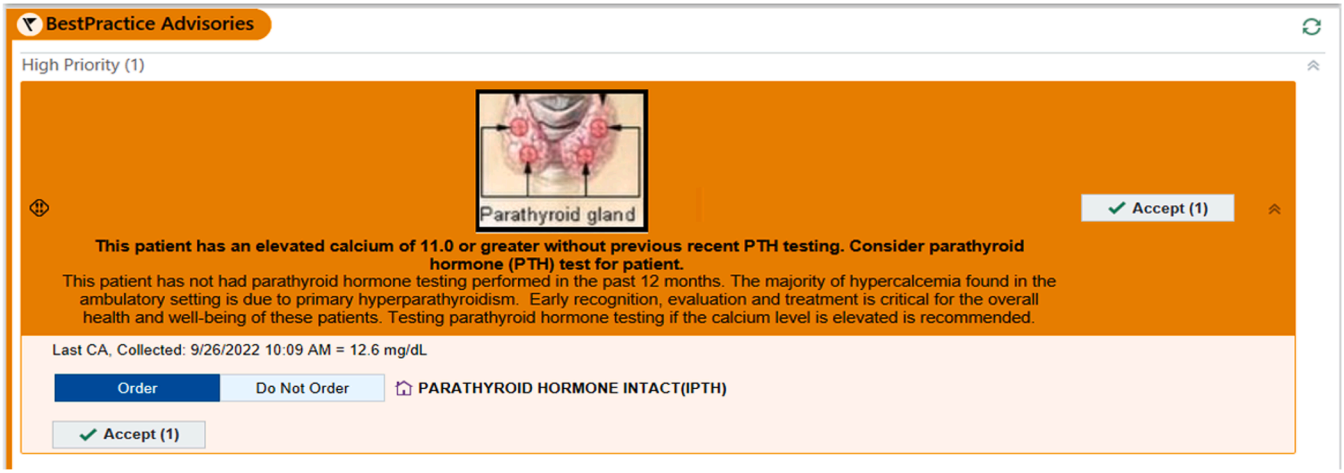

Figure 1. BPA banner. *BPA*, Best Practice Advisory.

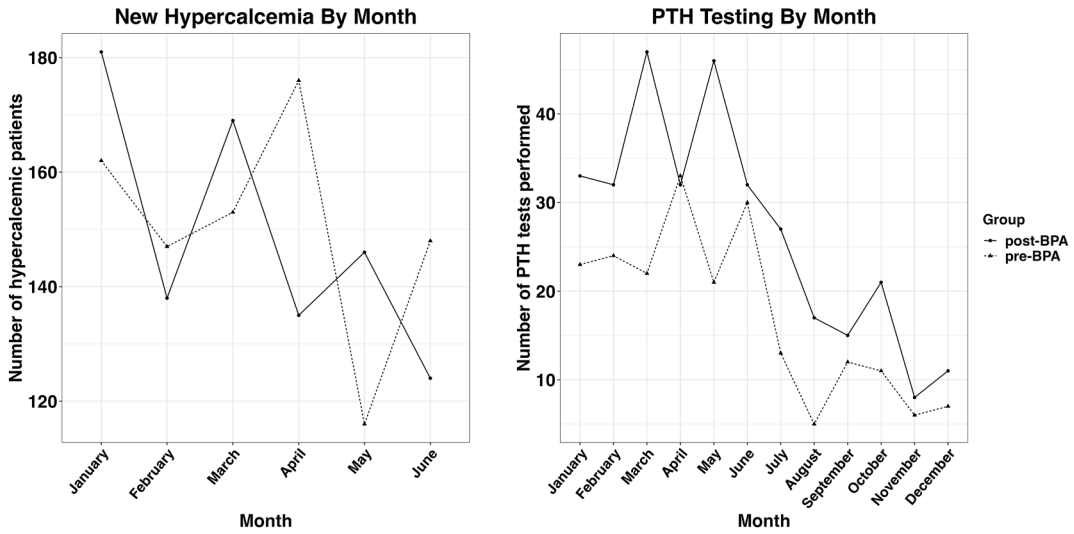

Figure 2. Hypercalcemia and PTH testing by month, demonstrating the greatest PTH testing frequency in the months of the study period that hypercalcemia initially was noted. PTH testing decreases as expected in July, because this is a month or more after hypercalcemia was noted in the pre-BPA and post-BPA groups. *BPA*, Best Practice Advisory; *PTH*, parathyroid hormone.

Results

State of hyperparathyroidism screening before BPA rollout

Within a 6-month period before the initiation of the BPA, 902 patients were identified with a serum calcium level greater than 11 mg/dL (Figure 2). Of these, 222 (24.61%) underwent PTH testing and almost 50% had a PTH level greater than 65 pg/mL (Figure 3). The majority of PTH testing occurred within close proximity to when the hypercalcemia was noted, with a median delay of 15 days (interquartile range, 1.25, 121.75). There were 131 patients with PTH testing ordered but not performed (14.52%). Of the patients who underwent PTH testing, 92 (41.44%) were referred to endocrinology or surgery for further evaluation, and 25 (27.17%) of those referred underwent parathyroidectomy (Table I, Figure 3).

BPA patient population and outcomes

Within a 6-month period after initiation of the BPA, 893 patients were identified with a serum calcium level $\geq$11 mg/dL (Table I). Of all patients with hypercalcemia, 346 (38.75%) underwent PTH testing and 176 (50.87%) of these had a PTH greater than 65 pg/mL (Figure 3). Again, the majority of PTH testing occurred within close proximity to when the hypercalcemia was noted, with a median delay of 27.5 days (interquartile range, 2, 139.75). There were 77 patients (8.62%) who had PTH testing ordered but not

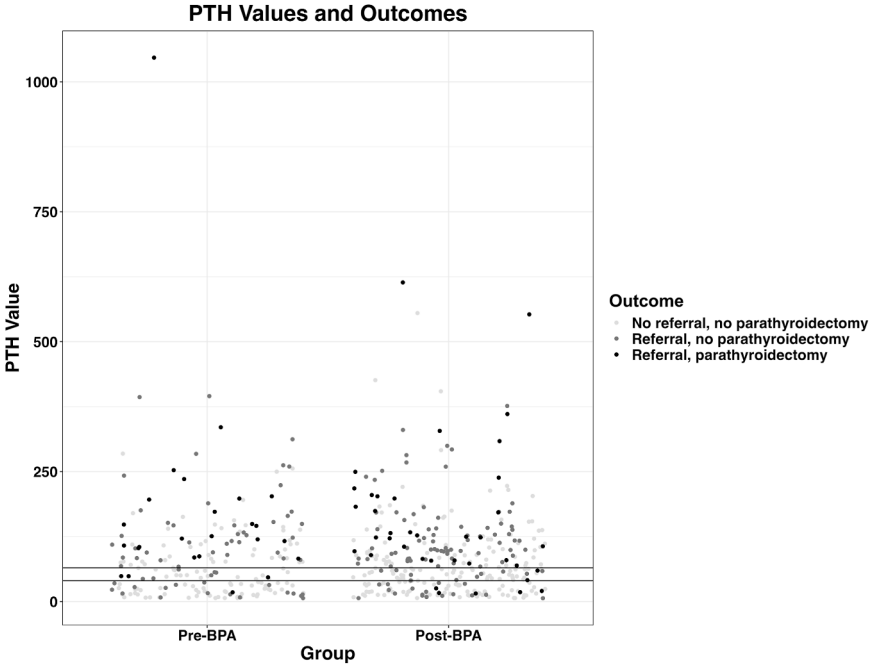

Figure 3. PTH values and outcomes in pre- and post-BPA groups. Horizontal lines correspond with PTH values of 40 and 65. *BPA*, Best Practice Advisory; *PTH*, parathyroid hormone.

Table I
Demographics, clinical characteristics, and outcomes of study population

	Pre-BPA group ($n = 902$)	Post-BPA group ($n = 893$)	*P* value
Serum calcium, *n* (%)			.54
11–11.9 mg/dL	787 (87.25%)	776 (86.90%)	
12–12.9 mg/dL	68 (7.54%)	61 (6.83%)	
≥13 mg/dL	47 (5.21%)	56 (6.27%)	
Age, yr, mean (SD)	66.24 (21.95)	63.13 (22.99)	<.01*
Sex, *n* (%)			.56
Female	582 (64.52%)	564 (63.16%)	
Male	320 (35.48%)	329 (36.84%)	
Race, *n* (%)			.05
Black or African American	107 (11.86%)	99 (11.09%)	
Other/unknown	27 (2.99%)	47 (5.26%)	
White or Caucasian	768 (85.14%)	747 (83.65%)	
Comorbidities, *n* (%)			
Nephrolithiasis	43 (4.77%)	56 (6.27%)	.18
CKD	190 (21.06%)	165 (18.48%)	.17
Osteopenia/osteoporosis	119 (13.19%)	112 (12.54%)	.72
Diabetes or prediabetes	284 (31.49%)	271 (30.35%)	.61
HTN	455 (50.44%)	444 (49.72%)	.78
HLD	400 (44.35%)	405 (45.35%)	.67
Obesity (BMI >30)	160 (17.74%)	135 (15.12%)	.14
Anxiety or depression	270 (29.93%)	258 (28.89%)	.64
Vitamin D deficiency	108 (11.97%)	121 (13.55%)	.32
0 comorbidities	195 (21.62%)	211 (23.63%)	.44
1 comorbidity	148 (16.41%)	125 (14.00%)	
2 comorbidities	159 (17.63%)	165 (18.48%)	
≥3 comorbidities	400 (44.35%)	392 (43.90%)	
PTH ordered and performed (*n*, % of all)	222 (24.61%)	346 (38.75%)	<.01*
PTH results (*n*, % of tested)			.04*
Normal (<40 pg/mL)	91 (40.99%)	108 (31.21%)	
40–65 pg/mL	28 (12.61%)	62 (17.92%)	
>65 pg/mL	103 (46.40%)	176 (50.87%)	
Referred to endocrinology or surgical subspecialist (*n*, % of all patients with PTH performed)	92 (41.44%)	142 (41.04%)	.93
Referral based on PTH level (*n*, % of specified PTH result group)			.47
PTH <40 pg/mL	23 (25.27%)	27 (25.00%)	
PTH 40–65 pg/mL	9 (32.14%)	12 (19.35%)	
PTH >65 pg/mL	60 (58.25%)	103 (58.52%)	
Underwent parathyroidectomy (*n*, % of all referred)	25 (27.17%)	38 (26.76%)	1.00

Percentages for "PTH results" are calculated on the basis of the total number of patients with a PTH ordered and performed. Percentages for "Referred to endocrinology or surgical subspecialist" are calculated on the basis of their respective groups. For example, 23 of 91 patients in the preintervention group with a PTH <40 were referred (25.27%).

BMI, body mass index; *BPA*, Best Practice Advisory; *CKD*, chronic kidney disease; *HLD*, hyperlipidemia; *HTN*, hypertension; *PTH*, parathyroid hormone; *SD*, standard deviation.

* Statistically significant.

performed. Of all patients who underwent PTH testing, 142 (41.04%) were referred to endocrinology or surgical specialists, and 38 (26.76% of those referred) underwent parathyroidectomy (Table I, Figure 3).

Overall, compared with the preintervention group, patients in the postintervention group were more likely to have PTH levels ordered by their health care provider and completed within the local health care system within 1 year of their first elevated serum calcium level (24.61% in the preintervention group vs 38.75% in the postintervention group, $P < .01$). There were no differences in rates of endocrinology or surgery referrals on the basis of group (41.44% in the preintervention group vs 41.04% in the postintervention group, $P = .93$). Furthermore, there was no difference in parathyroidectomy rates between groups (27.17% in the preintervention group vs 26.76% in the postintervention group, $P = 1.00$) (Table I).

In the postintervention group, patients with a serum calcium ≥12 mg/dL were no more likely to receive PTH testing compared with those with serum calcium of 11–11.9 mg/dL (47.01% vs 37.50%, $P = .05$; Table II). Patients who had PTH testing performed were more likely to be older in age (69.63 vs 59.01 years, $P < .01$) compared with the group of patients with hypercalcemia who did not undergo PTH testing (Figure 4, Supplementary Table S2). However, patients who were referred to endocrine or surgical specialists after PTH testing were younger on average than those who were not referred (67.59 vs 71.05 years, $P = .04$; Figure 4, Supplementary Table S3). There were no differences in rates of parathyroidectomy on the basis of demographic group (Supplementary Table S4).

Notably, 76.38% of patients in the postintervention group with elevated serum calcium had at least 1 comorbidity associated with PHPT (Table I). Compared with individuals with hypercalcemia with no comorbidities, PTH was less likely to be tested in those with 1 comorbidity ($P = .03$) and more likely to be tested in those with 2 ($P < .01$) or 3 or more ($P < .01$) comorbidities (Supplementary Table S2). However, those with comorbidities were no more likely to be referred for specialist consultation or undergo parathyroidectomy (Supplementary Tables S3 and S4).

Table II
Factors associated with PTH testing, referrals, and parathyroidectomy in post-BPA group

	PTH performed ($n = 346$)	Referral placed ($n = 142$)	Underwent parathyroidectomy ($n = 38$)
Serum calcium			
11–11.9 mg/dL	291 (37.50%)	125 (42.96%)	35 (28.00%)
≥12 mg/dL	55 (47.01%)	17 (30.91%)	3 (17.65%)
Age, yr, mean (SD)	69.63 (15.13)	67.59 (13.22)	64.97 (13.24)
Sex			
Male	116 (35.26%)	43 (37.07%)	10 (23.26%)
Female	230 (40.78%)	99 (43.04%)	28 (28.28%)
Race			
Black or African American	40 (40.40%)	18 (45.00%)	8 (44.44%)
White or Caucasian	294 (39.36%)	119 (40.48%)	29 (24.37%)
Other/unknown	12 (25.53%)	5 (41.67%)	1 (20.00%)
Comorbidities			
Nephrolithiasis	24 (42.86%)	12 (50.00%)	3 (25.00%)
CKD	72 (43.64%)	30 (41.67%)	7 (23.33%)
Osteopenia or osteoporosis	62 (55.36%)	24 (38.71%)	9 (37.50%)
Diabetes or prediabetes	119 (43.91%)	55 (46.22%)	12 (21.82%)
HTN	198 (44.59%)	83 (41.92%)	25 (30.12%)
HLD	181 (44.69%)	70 (38.67%)	15 (21.43%)
Obesity (BMI >30)	63 (46.67%)	25 (39.68%)	9 (36.00%)
Anxiety or depression	111 (43.02%)	51 (45.95%)	13 (25.49%)
Vitamin D deficiency	75 (61.98%)	35 (46.67%)	10 (28.57%)
0 comorbidities	49 (23.22%)	15 (30.61%)	3 (20.00%)
1 comorbidity	46 (36.80%)	25 (54.35%)	8 (32.00%)
2 comorbidities	70 (42.42%)	26 (37.14%)	9 (34.62%)
≥3 comorbidities	181 (46.17%)	76 (41.99%)	18 (23.68%)

Percentages for "PTH performed" use the total number of patients with hypercalcemia in the respective postintervention groups as the denominator ("Post-BPA Group" from Table I). For instance, 42.86% of patients with hypercalcemia in the post-BPA group who had PTH testing were noted to have a history of nephrolithiasis. Likewise, percentages for "referral placed" utilize total number of patients with PTH performed as the denominator, and percentages for "underwent parathyroidectomy" use total number of patients with referral placed as the denominator.
BMI, body mass index; *BPA*, Best Practice Advisory; *CKD*, chronic kidney disease; *HLD*, hyperlipidemia; *HTN*, hypertension; *PTH*, parathyroid hormone; *SD*, standard deviation.

Discussion

In this study, we found an increase in PHPT testing and diagnosis after the initiation of an EHR BPA but no increase in rates of referrals or parathyroidectomy. There were age-based patterns in PTH testing and referrals, with older individuals more likely to have PTH testing and younger individuals more likely to receive referrals to endocrinology or surgical subspecialists after a diagnosis of hyperparathyroidism. Patients with comorbidities related to PHPT were more likely to receive PTH testing but no more likely to be referred to a specialist or undergo parathyroidectomy.

After the BPA, the rate of PTH testing for patients at our institution with hypercalcemia only increased to approximately 40%. This leaves significant room for improvement. One option to further improve PTH testing may be to create reflex PTH testing for any hypercalcemia noted on outpatient laboratory tests. This was not an option at our health care system at the time of the study but may be an option at other institutions. Reflex testing minimally increases health care costs, but early diagnosis and surgical treatment of PHPT improves patient health and reduces lifetime health care costs.[16,17] Artificial intelligence algorithms may be useful in identifying patients with hypercalcemia and ordering additional testing. With use of reflex testing or artificial intelligence algorithms, it is critical that the clinicians within the system agree upon whose responsibility it is to follow-up on these added tests. Likely, this would fall to the ordering clinician, but this may contribute to additional clinical burden or have deleterious impacts on diagnosis and follow-up (if, for instance, the ordering clinician was unsure what to do with the result). Furthermore, the health system must ensure that insurance companies agree to cover PTH testing for any patient with hypercalcemia, lest the patient receive an unexpected bill for a test for which they did not consent. Additional improvement in PTH testing also may be gained by investing in clinician education via the use of medical lectures, CME, or e-mails. Specifically, clinicians should be educated that even asymptomatic patients with hyperparathyroidism often report improvement in quality of life after treatment of their hyperparathyroidism with parathyroidectomy.[7] There should be no hesitation to refer these patients to an endocrinologist or surgical subspecialist.

The rate of PTH testing after implementation of the BPA in this study is slightly lower than the rate of PTH testing (45–54%) after implementation of a similar BPA in a study by Dawood et al.[18] In that study, patients with secondary or tertiary hyperparathyroidism were excluded and patients had "chronic hypercalcemia" (ie more than 1 instance of hypercalcemia in a 6-month interval). Clinicians may be less likely to order PTH testing in patients with a single episode of hypercalcemia, and certainly if the etiology of hypercalcemia is already known. These factors may explain why our testing rates are lower. In contrast to the study by Dawood et al, we found an increased frequency of PTH testing when patients had comorbidities such as osteopenia/osteoporosis or metabolic syndrome. The relationship between PTH testing and osteopenia/osteoporosis may be partially explained by a well-developed fracture liaison service at our institution that aggressively evaluates etiologies of pathologic fractures. The relationship of increased PTH testing in patients with metabolic syndrome may be related to more frequent laboratory test monitoring and clinician visits in these patients.

The BPA introduced in this study did not improve rates of referral for endocrinology/surgical subspecialty evaluation or parathyroidectomy, even for patients with hypercalcemia, a PTH greater than 65 pg/mL, and PHPT-associated comorbidities. In both groups, just more than one half of the patients with documented hyperparathyroidism were referred for specialist evaluation. These results are not unexpected, because the average time from

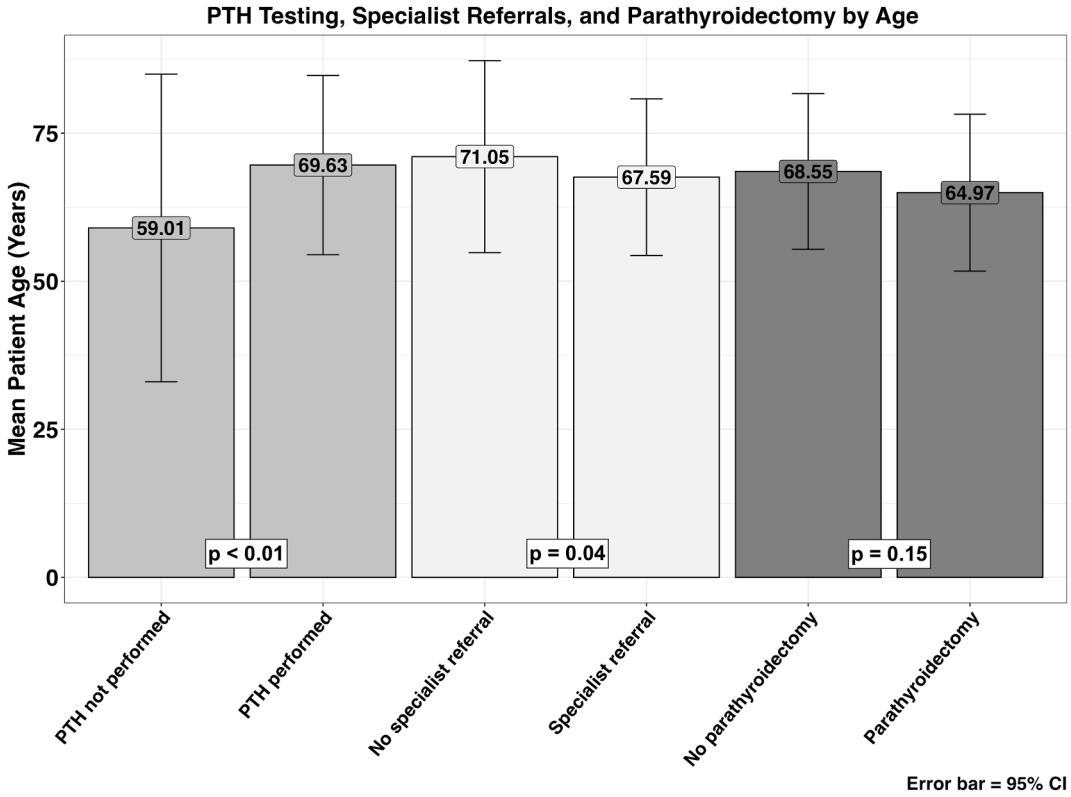

Figure 4. PTH testing, specialist referrals, and parathyroidectomy by age, where color represents outcome (PTH, specialist referral, parathyroidectomy). *PTH*, parathyroid hormone.

documentation of hypercalcemia to operation is 3.9 years.[19] Other reasons for the delay in referral and treatment for PHPT patients in this study may include clinicians overlooking the PTH results within the EHR or knowledge gaps about the treatment of HPT. This could be addressed with inclusion of "next steps" or links to educational materials within the BPA. Alternatively, it may be that clinicians discussed the new diagnosis of hyperparathyroidism with their patients, and the patients declined further evaluation or intervention (in our collective clinical experience, many of patients in our region delay medical or surgical evaluation for health problems until they become lifestyle-limiting or life-threatening).[20,21]

The age-related findings in PTH testing and referral patterns may be explained by population demographics and comorbidities. For example, older patients are more likely to have comorbidities such as renal disease, osteoporosis, or hypertension, which may have prompted more clinicians to order PTH testing. After an elevated PTH result, clinicians may have been more likely to "brush off" a slightly elevated result in older patients, or these patients may have been more likely to decline a referral or surgical intervention. These factors should be further investigated, and if present, may be addressed with patient and clinician education. Patient letters have been demonstrated to be effective in improving PTH testing, referrals, and treatment.[22] As such, something as simple as a patient pamphlet explaining hypercalcemia and PHPT may be a useful adjunct in improving diagnosis and treatment of PHPT.

One important implication of any BPA is the degree of clinician fatigue associated with frequent EHR reminders and additional EHR "clicks." Our BPA fired only in the ambulatory setting (on the basis of outpatient laboratory tests), which limited the overall burden of the BPA on clinicians. However, it did fire for any ambulatory clinician regardless of specialty. There was not a significant research and development period for our BPA, and there was limited technical support, both of which could have been leveraged to make the BPA more streamlined and targeted to a more tailored audience. The intended audience for a BPA as well as its associated administrative burden should be considered by any health system considering the implementation of similar EHR interventions.

This study has several limitations. Clinical care is a dynamic process, and changes in PTH testing and referrals in our study may be related to factors distinct from the BPA such as clinician turnover, cultural shifts in PTH testing, or changes in clinician education or individual practices. Also, our study is a single-site study from one institution in Appalachia, which may not generalize well to other institutions or patient populations. Furthermore, our study did not isolate patients with PHPT and a number of patients with secondary or tertiary hyperparathyroidism were likely included. This may have influenced referral patterns and recommendations for parathyroidectomy. Lastly, our BPA did not require that an updated calcium level was drawn at the time of the PTH testing, even when the initial abnormal calcium was collected months before the PTH. Clinically, this may have affected the interpretation of the laboratory studies and likely led to repeat laboratory draws and increased costs to the patients. In the future we will consider amending the BPA to promote the order of a PTH panel with updated calcium in addition to creatinine, phosphorus, and intact PTH.

In conclusion, a BPA aimed at improving diagnosis of PHPT was moderately effective at improving PTH testing but did not improve rates of referrals for surgical or nonsurgical management of the

condition. Reflex testing and improved patient and clinician education may further improve diagnosis and treatment of HPT.

Funding/Support

No extramural funding was used for this study. Funds from an institutional educational grant were used for statistician support.

Conflict of Interest/Disclosure

The authors have no relevant financial disclosures.

CRediT authorship contribution statement

Rebecca S. Gates: Writing – review & editing, Writing – original draft, Visualization, Project administration, Investigation, Formal analysis. **Kristin McCoy:** Writing – review & editing, Investigation, Formal analysis. **Jonathan Stewart:** Writing – review & editing, Methodology, Conceptualization. **Andrew J. Behnke:** Writing – review & editing, Methodology, Conceptualization. **Adegbenga Bankole:** Conceptualization, Writing – review & editing, Methodology. **Theresa Vallia:** Writing – review & editing, Formal analysis. **Michael S. Nussbaum:** Writing – review & editing, Methodology. **Daniel Tershak:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at [https://doi.org/10.1016/j.surg.2025.109706].

References

1. Pokhrel B, Leslie SW, Levine SN. Primary hyperparathyroidism. In: *StatPearls*. Treasure Island, FL: StatPearls Publishing; 2024.
2. Yeh MW, Ituarte PHG, Zhou HC, et al. Incidence and prevalence of primary hyperparathyroidism in a racially mixed population. *J Clin Endocrinol Metab*. 2013;98:1122.
3. Axelsson KF, Wallander M, Johansson H, et al. Analysis of comorbidities, clinical outcomes, and parathyroidectomy in adults with primary hyperparathyroidism. *JAMA Netw Open*. 2022;5:e2215396.
4. Bibik EE, Dobreva EA, Elfimova AR, et al. Primary hyperparathyroidism in young patients is associated with metabolic disorders: a prospective comparative study. *BMC Endocr Disord*. 2023;23:1–9.
5. Ionova TI, Buzanakov DM, Chernikov RA, et al. Quality of life in patients with primary hyperparathyroidism before and after parathyroidectomy: long term single center experience. *BMC Endocr Disord*. 2023;23:1–12.
6. Kanis JA, Harvey NC, Liu E, et al. Primary hyperparathyroidism and fracture probability. *Osteoporos Int*. 2023;34:489–499.
7. Wilhelm SM, Wang TS, Ruan DT, et al. The American Association of Endocrine Surgeons guidelines for definitive management of primary hyperparathyroidism. *JAMA Surg*. 2016;151:959–968.
8. Charles PY, Letavernier E, Périé S, Gauthé M, Daudon M, Haymann JP. Effect of parathyroidectomy on renal stone recurrence. *Urolithiasis*. 2021;49:327–334.
9. Lundstam K, Pretorius M, Bollerslev J, et al. Positive effect of parathyroidectomy compared to observation on BMD in a randomized controlled trial of mild primary hyperparathyroidism. *J Bone Miner Res*. 2023;38:372–380.
10. Livschitz J, Yen TWF, Evans DB, Wang TS, Dream S. Long-term quality of life after parathyroidectomy for primary hyperparathyroidism: a systematic review. *JAMA Surg*. 2022;157:1051–1058.
11. Press DM, Siperstein AE, Berber E, et al. The prevalence of undiagnosed and unrecognized primary hyperparathyroidism: a population-based analysis from the electronic medical record. *Surgery*. 2013;154:1232–1238.
12. Balentine CJ, Xie R, Kirklin JK, Chen H. Failure to diagnose hyperparathyroidism in 10,432 patients with hypercalcemia: opportunities for system-level intervention to increase surgical referrals and cure. *Ann Surg*. 2017;266:632.
13. Charoensri S, Bashaw L, Dehmlow C, Ellies T, Wyckoff J, Turcu AF. Evaluation of a best-practice advisory for primary aldosteronism screening. *JAMA Intern Med*. 2024;184:174–182.
14. Pinkney K, Ahmed AM, Bose S, Breeden M, Smeds MR. Interacting with best practice advisory (BPA) notifications in the electronic medical record significantly improves screening rates for abdominal aortic aneurysms. *JVS-Vasc Insights*. 2024;2:100037.
15. Siyam FF, Klachko DM. What is hypercalcemia? The importance of fasting samples. *Cardiorenal Med*. 2013;3:232–238.
16. Zanocco K, Angelos P, Sturgeon C. Cost-effectiveness analysis of parathyroidectomy for asymptomatic primary hyperparathyroidism. *Surgery*. 2006;140:874–882.
17. Zanocco K, Heller M, Sturgeon C. Cost-effectiveness of parathyroidectomy for primary hyperparathyroidism. *Endocr Pract*. 2011;17:69–74.
18. Dawood NB, Shu ML, Tseng CH, et al. An electronic medical record–based decision support tool for the diagnosis of primary hyperparathyroidism. *JAMA Intern Med*. 2022;182:1000–1002.
19. Naples R, French JC, Thomas JD, Khandelwal C, Rosen MJ, Lipman JM. Utilization of a quality reporting system to increase faculty participation in resident operative assessment. *Surgery*. 2021;169:483–487.
20. Stanzak A, Oliver-Lemieux R. Appalachians and health: the impact of history and culture on healthcare decisions and disparities. In: *Cultural Issues in Healthcare: Emerging Challenges and Opportunities*. Cham: Springer International Publishing; 2023:93–102.
21. Falk DS, Tooze JA, Winkfield KM, et al. Factors associated with delaying and forgoing care due to cost among long-term, Appalachian cancer survivors in rural North Carolina. *Cancer Surviv Res Care*. 2023;1:2270401.
22. Behnke AJ, Tershak DR, Abel WF, Bankole AA. A therapeutic approach to primary hyperparathyroidism: a collaborative evaluation between endocrinology and surgery. *Cureus*. 2023;15:e34157.

Discussion

Dr Sally Carty (Pittsburgh, PA): This is an interesting study, very well presented. Two questions. One, as you and your group know, the hallmark of diagnosis of primary hyperparathyroidism is not a single elevated calcium, it is multiple elevations. Did you look at whether subsequent calcium levels were elevated in your data set?

Dr Rebecca Gates (Carilion Clinic - Virginia Tech Carilion Clinic School of Medicine): In this study, we did not look at additional levels. We purposely chose a level that was a little bit higher. The cut-off at our institution is 10.4 for normal calcium. And because we were trying to see how this worked with a single calcium level, we chose a number that was a bit higher. But I do imagine that the majority of these patients had repeat laboratory tests at some point.

Dr Carty: The other question is just an idea—what about sending a letter to the patient? Is it legal in Alabama?

Dr Gates: It is legal. Our institution had previously tried something similar to this but did not have great success. It did increase screening to some extent, but less than the jump that we noticed with the Best Practice Advisory (BPA), but certainly would be something you could use in conjunction. I think that would help educate patients about their disease as well and allow them to come into any referral appointments or into their primary care physicians (PCP) office with additional questions.

Dr Carolyn Seib (Stanford University, Palo Alto): Great presentation. You really touched on a lot of the key points. Were you able to look into any of the notes to see whether the diagnosis was recognized for those patients who had it, and whether anyone

documented a discussion about the risks and benefits of treatment? I think it's kind of unique in your study that, as you said, people had relatively severe biochemical profiles at least at one time point. So one would think that these would be patients who may be more likely to be referred (for surgery). I'm just curious whether you think (primary hyperparathyroidism) was recognized, and whether PCPs or whoever else would be having a discussion about the options (recognized it) or if it's maybe being ignored and patients don't know that there's a treatment option, such as parathyroidectomy.

Dr Gates: Sure. I think that's a good next step. We did not look into whether the PCP or whoever ordered the laboratory tests actually recognized the diagnosis or documented it in the chart. I think at least some of the ordering clinicians were recognizing the diagnosis. In regards to the PCP question, it is not uncommon that as surgeons, we present our patients with options for surgery, and they say, "No, I don't want a surgery." So, I wonder if for some patients, the PCP talked to them about referral, and they said, "No, I'm not interested in surgery/treatment," and so they were never referred. That's certainly something that we can look at in the future, perhaps through qualitative means and conversations with the PCPs in our area.

Dr Dave Schneider (University of Wisconsin, Madison): Nice study, very nicely presented. Since you are using the term BPA, I assume that you are working in Epic. I'm curious a little bit about the intervention itself. Do you have any data on how many people interacted with the BPA and what the choices they selected?

Dr Gates: We didn't collect that data, and I think that's a limitation of our study. However, after talking with some of our co-authors who interacted with the BPA, we included patients who had these laboratory studies ordered through other means (not necessarily just by clicking on the BPA). Our co-authors told us that they would be prompted with the BPA, say, in the office, but then not order the studies at that time, and go back later, at the end of the day or the next day to order them. We changed the inclusion criteria to make sure we captured those patients (even if the BPA was blown off initially). But certainly, that is a metric that would be useful to look into.