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Original Research

Assessment of Speckle-Tracking Echocardiography in Primary Hyperparathyroidism

Sadettin Öztürk [1], Esma Gülsun Arslan Cellat [2], Eren İmre [3 *], İrfan Veysel Düzen [4], Erhan Saraçoğlu [5], Osman Büyükçelebi [4], Suzan Tabur [6]

[1] Department of Endocrinology and Metabolism Diseases, Gaziantep City Hospital, Gaziantep, Türkiye
[2] Department of Endocrinology and Metabolism Diseases, Dr. Ersin Arslan Research and Training Hospital, Gaziantep, Türkiye
[3] Department of Endocrinology and Metabolism Diseases, Marmara University, İstanbul, Türkiye
[4] Department of Cardiology, Gaziantep University, Gaziantep, Türkiye
[5] Department of Cardiology, Etlik City Hospital, Ankara, Türkiye
[6] Department of Endocrinology and Metabolism Diseases, Gaziantep University, Gaziantep, Turkiye

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Corresponding Author
Eren İmre, MD
Address: Department of Endocrinology and Metabolism, Marmara University School of Medicine, İstanbul, Türkiye
E-mail: eren.imre@marmara.edu.tr

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ABSTRACT

Objective: Primary hyperparathyroidism (PHPT) has been associated with increased cardiovascular morbidity and mortality. Although conventional echocardiography is frequently used to evaluate cardiac function, it may fail to detect early myocardial changes. Speckle-tracking echocardiography (STE) provides greater sensitivity in identifying subclinical cardiac dysfunction. This study investigated systolic and diastolic functions of the left ventricle (LV) using STE in PHPT patients and examined their associations with clinical and biochemical variables.

Methods: A total of 39 PHPT patients and 40 healthy controls were enrolled. PHPT diagnosis was based on elevated serum calcium and parathormone (PTH) levels, confirmed by imaging. Patients with comorbid conditions such as hypertension, diabetes, and chronic kidney disease were excluded. All individuals of patient and control groups were performed both conventional echocardiography and STE. Global longitudinal strain (GLS) and additional parameters of echocardiographic investigation were measured. Biochemical assessments included serum calcium level, phosphorus, 25-hydroxy vitamin D, and PTH levels. Statistical comparisons and correlation analyses were performed.

Results: PHPT patients showed higher calcium, parathormone levels, and lower phosphorus and vitamin D levels than controls. GLS values were considerably lower in the PHPT group, indicating subclinical myocardial dysfunction despite intact ejection fraction ($p < 0.05$). GLS and levels of calcium, phosphorus, and PTH were found to be significantly correlated ($p < 0.05$).

Conclusion: STE effectively detected early myocardial dysfunction in PHPT patients and demonstrated associations with biochemical markers. These results support the use of STE for early cardiac assessment in PHPT and underline the need for further studies to confirm these findings.

Keywords: echocardiography, hyperparathyroidism, myocardial, speckle-tracking

INTRODUCTION

Primary hyperparathyroidism (PHPT) is an endocrine disorder that is characterized by high serum calcium and low phosphate levels due to excessive parathormone (PTH) secretion [1]. This condition affects multiple organs, particularly the bones, kidneys, and nervous system [2]. Cardiovascular involvement is common in PHPT, including left ventricular (LV) hypertrophy, diastolic dysfunction, hypertension, and vascular abnormalities, contributing to increased risks of myocardial infarction, heart failure, and stroke [3]. The underlying mechanisms may involve calcium-induced cardiac hypertrophy and direct effects of PTH on cardiomyocytes and vascular smooth muscle through protein kinase C action [4].

Although PHPT patients often exhibit structural and vascular cardiac changes, conventional functional metrics of LV systole, such as ejection fraction, fractional shortening, and cardiac index, typically remain within normal limits [5,6]. The presence of LV diastolic dysfunction is controversial, with inconsistent findings regarding reduced early-to-late diastolic flow (E/A) ratios and prolonged isovolumetric relaxation time (IVRT) [5,6].

Echocardiography is a widely used, non-invasive method for assessing cardiac function. However, traditional parameters may fail to detect early myocardial dysfunction, as longitudinal function often declines before radial and circumferential function, preserving ejection fraction [7–9]. Strain echocardiography, derived from color Doppler imaging, allows sensitive evaluation of myocardial deformation and can identify subtle early dysfunction. In PHPT, strain analysis may reveal cardiac abnormalities not detected by routine echocardiography, offering a valuable tool for early cardiovascular risk assessment and monitoring.

Main Points

- PHPT patients without overt cardiovascular disease exhibit significantly altered myocardial strain parameters, suggesting the presence of subclinical myocardial involvement detectable by speckle-tracking echocardiography.
- Elevated PTH and serum calcium levels are associated with impaired myocardial deformation.
- Speckle-tracking echocardiography may serve as an early diagnostic and risk stratification tool in PHPT.

MATERIALS AND METHODS

This study analysed 39 individuals who had the diagnosis of primary hyperparathyroidism (PHPT) and who were evaluated between 2019 and 2020 at the Endocrinology and Metabolic Diseases Clinic of Gaziantep University, alongside 40 healthy volunteers as controls. PHPT diagnosis was based on increased serum calcium and parathormone (PTH) levels, with identification of a parathyroid adenoma via ultrasonographic imaging and/or sestamibi scintigraphy. All individuals in this study provided written informed consent to be included and examined. This study was approved by the Clinical Research Ethics Committee of Gaziantep University at its meeting dated February 5, 2020, under protocol code 52 and decision number 2020/52. It was executed in compliance with the tenets of the Declaration of Helsinki.

The criteria for inclusion were age ≥18 years, verified primary hyperparathyroidism, and lack of comorbidities. Individuals with diabetes, hypertension, valvular heart disease, coronary artery disease, chronic renal or liver failure, or those taking steroids, digoxin, antihypertensives, or diuretics were not included. Total cholesterol level over 200 mg/dL, triglyceride level over 150 mg/dL, and HDL cholesterol level under 40 mg/dL for men or under 50 mg/dL for women were accepted as indicators of hyperlipidemia. People who smoked 5 to 10 packs of cigarettes in the previous year and who currently smoke every day were classified as cigarette smokers.

Laboratory and clinical parameters, including PTH, calcium, phosphorus, creatinine, 24-hour urinary calcium, bone mineral density, renal stones, vitamin D levels, and speckle-tracking echocardiography findings, were analyzed to compare PHPT patients with healthy controls. The study also investigated associations between echocardiographic parameters and organ involvement, such as osteoporosis and renal stone formation, to assess the cardiovascular impact of PHPT.

Laboratory Parameters

Blood samples for biochemical tests were taken from the antecubital vein, following an overnight fast, between 08:00 and 09:00, while participants were at rest. Patients and controls had their serum levels of calcium, phosphorus, albumin, parathyroid hormone (PTH), and 25-hydroxy vitamin D (25-OH vitamin D) tested. A chemiluminescent enzyme-labeled immunoradiometric assay (Siemens Immulite 2000, UK) with an analytical sensitivity of 3.0 pg/mL, reference range of 11–65 pg/

mL, intra-assay coefficient of variation (CV) of 4.2–5.7%, and inter-assay CV of 6.3–8.8% was used to measure parathyroid hormone (PTH). Using Chromsystems kits, high-performance liquid chromatography (HPLC) (Agilent 1,200, Germany) was utilised to assess serum 25-hydroxy vitamin D (25-OH vitamin D), with normal values of 20–120 µg/L and intra- and inter-assay CVs of 5% and 7%, respectively.

Conventional Echocardiography

A Vivid E9 device (GE) with a 2–4 MHz phased-array transducer was used to perform echocardiographic imaging on patients in the left lateral decubitus posture. M-mode, pulsed Doppler, 2-dimensional, and color flow Doppler analyses were carried out. The American Society of Echocardiography criteria were followed while measuring the interventricular septum thickness, thickness of the posterior wall, left ventricular (LV) end-diastolic diameter, and left atrial antero-posterior diameter from the parasternal long-axis view. Simpson's approach was the method to calculate the ejection fraction (EF) of the left verntricule, and the Devereux formula normalized to body surface area was used to get the LV mass. E- and A-wave velocities, the E/A ratio, and the E-wave deceleration time were recorded at the mitral valve tips using a pulsed Doppler to measure diastolic function. Additionally, early (e') and late (a') cardiac velocities were measured using tissue Doppler imaging at the septal and lateral mitral annulus.

Speckle-tracking Echocardiography

Left ventricular (LV) longitudinal strain (LS) was evaluated using an automated function imaging (AFI) protocol. Two-dimensional grayscale images were recorded from apical 3-, 4-, and 2-chamber views at 50–70 frames/s, with three consecutive cardiac cycles acquired per view. AFI analysis was performed using EchoPAC software (version 113.1.7, GE Healthcare). The end-systolic frame was identified by marking aortic valve closure in the apical long-axis view, and the interval between R-wave and valve closure was measured. After selecting two basal points at the mitral annulus and one at the apex, semi-automated tracking was generated and manually optimized. Each apical view produced six LV segments, and tracking quality and strain values were evaluated. Mean LS was measured for every view, and global longitudinal strain (GLS) was obtained as their average, expressed as a negative value indicating myocardial deformation.

Statistical Analysis

SPSS version 11.5 (SPSS Inc., Chicago, IL, USA) was performed for statistical analysis. Continuous variables were evaluated for normalcy by the Shapiro-Wilk test. For variables that are continuous, descriptive statistics were provided as the median (interquartile range); variables that are categorical were given as numbers and percentages. Non-parametric tests were used because continuous variables had non-normal distributions. The Chi-square test was employed for categorical data, and the Mann-Whitney *U* test was utilized to examine differences between independent groups. Statistical significance was accepted as a *p*-value under 0.05.

RESULTS

Data from 39 patients diagnosed with primary hyperparathyroidism (PHPT) (29 females/10 males) and 40 healthy volunteers (35 females/5 males) were analyzed. Age, gender, weight, body mass index (BMI), calcium, albumin, parathyroid hormone (PTH), creatinine, phosphorus, and 25-OH vitamin D levels were compared between the two groups (Table 1). A statistically significant difference was observed between the two groups for these variables. Since the control group consisted of healthy individuals, 24-hour urinary calcium excretion levels were not measured in this group. None of the controls had a history of renal stones or osteopenia/osteoporosis.

A statistically significant difference in age was not found between the groups (Table 1). Serum calcium and parathyroid hormone levels were higher in the patient group, whereas phosphorus and 25-OH vitamin D levels were lower. In the patient group, 24-hour urinary calcium excretion levels were found to be above the reference range.

When comparing conventional echocardiographic findings between the PHPT patients and healthy controls, statistically significant differences were observed in ejection fraction (EF), ejection time (ET), in the end-diastolic diameter of left ventricule (LVEDD), end-systolic diameter of the left ventricule (LVEDS), interventricular septal thickness (IVS), deceleration time (DT), isovolumic contraction time (IVCT), and myocardial performance index (MPI) parameters. However, no significant differences were found in posterior wall thickness (PW), left atrium, early diastolic transmitral flow velocity (E wave), late diastolic transmitral flow velocity (A wave), E/A ratio, or isovolumic relaxation time (IVRT) parameters (Table 2).

Table 1. Demographical, physical examination and laboratory findings inpatients with primary hyperparathyroidism and healthy control subjects

Parameters	Primary hyperparathyroidism (n:39)	Control (n:40)	p
Age (year)*	49.7 (14.08)	38.4 (12.26)	**0.719**
Sex (female/male)*	29/10	35/5	**0.229**
Weight (kg)*	80.9 (17.39)	75.5 (12.56)	**0.960**
Height (cm)	163.5 (7.88)	167.2 (6.14)	**0.760**
Calcium (mg/dl)*	11.8 (0.9)	10.0 (0.3)	**<0.050**
Albumin (g/dL)*	4.00 (0,3)	4.10 (0.4)	**0.040**
Parathyroid hormone (pg/ml)*	203 (122)	41 (19)	**<0.050**
Creatinin (mg/dL)*	0.72 (0.28)	0.8 (0.1)	0.090
Phosporus (mg/dL)*	2.5 (0.7)	3.45 (0.5)	**<0.050**
25-OH vitaminD (ng/L)*	12.0 (8.0)	35 (5.8)	**<0.050**
24-h urinary calcium excretion (mg/day)	712	-	
Nephrolithiasis (n)	6	-	
Osteopenia (n)	19	-	

* median(interquartile range), p <0.050 indicate statistical significance

Table 2. M-mode, two dimensional echocardiography, and pulse Doppler echocardiography measurements inpatients with primary hyperparathyroidism and healthy control subjects

Parameters	Primary hyperparathyroidism (n:39)	Control (n:40)	p
LVEDD (mm)	48.00 (6.0)	46.00 (7.0)	**0.038**
LVESD (mm)	30.00 (5.0)	28.0 (6.0)	**<0.05**
LVESD (mm)	10.0 (2.0)	9.0 (2.0)	**0.047**
PW (mm)	9.0 (2.0)	9.0 (1.0)	0.599
EF (%)	60.0 (5.0)	65.0 (9.0)	**<0.05**
Left Atrium (mm)	33.0 (5.0)	32.0 (7.0)	0.382
E wave (cm/sn)	0.70 (0.20)	0.80 (0.5)	0.028
A wave (cm/sn)	0.60 (0.10)	0.50 (0.4)	0.934
E/A	1.30 (0.6)	1.50 (0.7)	0.147
DT (ms)	182.0 (40.0)	154.0 (65.0)	**<0.050**
IVRT (ms)	88.0 (14.0)	84.0 (20.0)	0.696
IVCT (ms)	59.0 (6.0)	68.0 (25.0)	**<0.050**
ET (ms)	286.0 (20.0)	264.0 (69.0)	**0.001**
MPI	0.50 (0.1)	0.60 (0.90)	**0.018**

p \ 0.050: indicate statistical significance, LVEDD: Left ventricle end diastolic diameter, LVESD: left ventricle end systolic diameter, IVS: interventricular septum, PW: Posterior wall, EF: Ejection fraction, EE: arly diastolic transmitral flow velocity, LVEDS: A Late diastolic transmitral flow velocity, DTD: eceleration time, IVRT: isovolumetric relaxation time, IVCT: isovolumetric contraction time, ET: Ejection time, MPI: Myocardial performance index

Longitudinal strain values were compared between the patient group with primary hyperparathyroidism (PHPT) and the healthy controls, revealing a statistically significant distinction between these groups (Table 3).

The correlation between calcium, phosphorus, parathyroid hormone (PTH), and 25-OH vitamin D levels and speckle tracking echocardiography parameters was analyzed, revealing a statistically significant distinction between the two groups (Table 3). However, no correlation was found between speckle tracking echocardiography findings and other parameters such as bone mineral density, presence of renal stones, 24-hour urinary calcium levels, or body mass index (BMI).

DISCUSSION

Primary hyperparathyroidism (PHPT) has notable effects on the cardiovascular system, including hypertension, endothelial and vascular smooth muscle dysfunction, and valvular or

Table 3. Comparisons of longitudinal strain among groups and the results of correlation analyses of all individuals in the study

Parameters	Primary hyperparathyroidism (n:39)		Control (n:40)					p
GLS A3C	18.7(3.20)		20.45(1.98)					**<0.050**
GLS A4C	18.8(4.00)		20.45(2.25)					**<0.050**
GLS A2C	18.8(5.00)		21.20(2.70)					**0.048**
GLS Average	19.00(3.10)		20.1(0.20)					**0.031**
Posterior Wall	17.00(4.00)		20.00(3.00)					**<0.050**
Lateral Wall	16.00(4.00)		20.00(4.00)					**<0.050**
İnferior Wall	17.00(6.00)		19.00(4.00)					**<0.050**
Anterior Wall	18.00(4.00)		18.00(3.00)					**<0.050**
Anterior Apex	20.00(7.00)		26.50(3.50)					**<0.050**
İnferior Apex	22.00(6.00)		26.00(3.75)					**<0.050**
Lateral Apex	21.00(7.00)		27.00(3.50)					**<0.050**
Septal Apex	22.00(7.00)		27.00(5.00)					**<0.050**
	Calcium		**Phosphorus**		**PTH**		**Vit. D**	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
GLS A3C	0.551	<0.050	0.557	<0.050	0.553	<0.050	0.420	**<0.050**
GLS A4C	0.526	<0.050	0.439	<0.050	0.453	<0.050	0.424	**<0.050**
GLS A2C	0.261	0.022	0.296	0.009	0.180	0.118	0.199	**0.082**
GLS Average	0.324	0.004	0.254	0.026	0.245	0.032	0.250	**0.029**
Posterior Wall	0.601	<0.050	0.584	<0.050	0.570	<0.050	0.483	**<0.050**
Anterior Septal Wall	0.509	<0.050	0.466	<0.050	0.414	<0.050	0.304	**0.007**
Lateral Wall	0.555	<0.050	0.452	<0.050	0.539	<0.050	0.517	**<0.050**
İnferior Wall	0.528	<0.050	0.548	<0.050	0.515	<0.050	0.464	**<0.050**
Anterior Wall	0.342	0.002	0.351	0.002	0.324	0.004	0.344	**0.002**
Anterior Apex	0.558	<0.050	0.633	<0.050	0.537	<0.050	0.505	**<0.050**
İnferior Apex	0.676	<0.050	0.698	<0.050	0.607	<0.050	0.518	**<0.050**
Lateral Apex	0.613	<0.050	0.524	<0.050	0.541	<0.050	0.514	**<0.050**
Septal Apex	0.621	<0.050	0.580	<0.050	0.599	<0.050	0.553	**<0.050**

* median (interquartile range), $p < 0.050$ indicate statistical significance, GLS: global longitudinal strain, A3C: apical 3 chamber, A4C: apical 4 chamber, A2C: apical2chamber

myocardial calcifications, all of which contribute to increased cardiovascular mortality [10]. Since Ronni-Sivula's initial report in 1985 demonstrating higher cardiovascular mortality in PHPT, several large-scale studies have confirmed these findings. Although no single parameter has been definitively established to predict mortality, elevated presurgical serum calcium (Ca) and parathyroid hormone (PTH) levels, along with increased adenoma weight, have been suggested as potential contributors. Some studies have reported increased mortality and higher myocardial infarction risk even in individuals with blood calcium levels at the upper bound of the normal serum levels [11,12].

In this study, as expected, serum PTH and calcium levels were considerably higher in PHPT individuals, while phosphorus levels were lower than those of individuals without the disease. The relationships between PTH, calcium, phosphorus, 25-OH vitamin D levels, and speckle-tracking echocardiography findings were examined, and statistically significant associations were identified. Despite the absence of known cardiovascular disease, patients with PHPT exhibited significantly altered strain parameters compared with healthy controls. This result provides a suggestion that strain abnormalities may serve as a predictive value and could reveal early myocardial involvement before clinical cardiovascular disease becomes detectable. Previous studies similarly reported that individuals with higher calcium levels—but without a diagnosed cardiovascular condition—face increased risks of myocardial infarction and cardiac mortality. Elevated PTH levels have also been pertaining to increased cardiovascular risk in other studies [5,13].

The presence of elevated serum PTH and calcium levels in PHPT patients, even without overt cardiovascular disease, highlights the clinical importance of advanced imaging modalities. Speckle-tracking echocardiography provides detailed strain assessments that may detect early myocardial impairment not identified by conventional echocardiography. In this research, strain values were significantly different between PHPT patients and healthy controls across all parameters, supporting the idea that strain imaging can serve as an early diagnostic tool in this population.

Increased rates of peripheral arterial disease, coronary artery disease, myocardial infarction, cerebrovascular events, and heart failure have all been linked to elevated blood parathormon, which has been proven to be an independent risk factor for cardiovascular disease [14]. Higher parathormon levels have been linked to cardiovascular disease and aortic calcification, according to a study by Buizert et al. [15]. Cardiomyocytes also have receptors for parathormon and parathormon-related peptides. Through these receptors, elevated serum PTH encourages calcium influx into heart cells, which activates protein kinase C and causes hypertrophic expansion. Experimental studies have shown that parathormone fragments (1–34 and 28–48) stimulate the synthesis of protein and selectively induce cytosolic creatine kinase in adult rat cardiomyocytes [4]. One of the other studies demonstrated that treatment of neonatal rat ventricular cardiomyocytes with parathormone 1–34 for 24 hours induced hypertrophy, characterized by increased cell diameter, enhanced protein synthesis, and elevated ANP mRNA expression through the mitogen-activated protein kinase (MAPK) signaling pathway [16]. Collectively, these findings suggest that PTH directly exerts hypertrophic effects on cardiomyocytes. Consistent with these data, the altered strain values observed in PHPT patients support the hypothesis that myocardial involvement may begin earlier than what conventional imaging can detect.

Beyond the direct cardiovascular effects of parathormone, low 25-OH vitamin D levels have also been associated with elevated cardiovascular risk [17]. A recent meta-analysis reported that individuals with the lowest vitamin D levels had significantly higher risks of total cardiovascular disease, cardiovascular mortality, coronary artery disease, and stroke compared with those with the highest levels [18]. In this current study, vitamin D levels were lower in PHPT patients and higher in controls, aligning with evidence that vitamin D deficiency contributes to cardiovascular risk.

Although statistically significant differences were observed in LVEDD, left ventricle end systolic diameter (LVESD), interventricular septal thickness, and left ventricular ejection fraction (LVEF) between patients with primary hyperparathyroidism and the control group, these values remained within normal reference ranges in both groups, suggesting limited clinical significance. Likewise, conventional diastolic function parameters did not demonstrate consistent or clinically significant abnormalities. In contrast, despite preserved LVEF, global and segmental longitudinal strain values were lower in patients with primary hyperparathyroidism, suggesting the presence of early or subclinical myocardial functional alterations that may not be detected by conventional echocardiography. Therefore, speckle-tracking echocardiography may provide incremental value in the assessment of early cardiac involvement in patients with primary hyperparathyroidism. Similarly, the

literature indicates that strain echocardiography is a highly sensitive technique capable of detecting myocardial dysfunction at an early stage [19]. Even in cases where conventional echocardiographic parameters, such as left ventricular ejection fraction and diastolic function indices, remain within normal ranges, strain echocardiography, particularly global longitudinal strain (GLS) and global circumferential strain (GCS), has been shown to identify subclinical cardiac involvement. Therefore, strain echocardiography appears to provide incremental value for the early assessment of myocardial dysfunction [19].

Limitations

This study's non-prospective design and small sample size, which may restrict its ability to be generalized, are its main limitations.

A significant age disparity was observed between the study groups, likely attributable to the stringent exclusion of individuals with cardiovascular risk factors during the selection of the control cohort. Although this difference may have acted as a potential confounding factor, it does not detract from the significance of the strain abnormalities identified.

CONCLUSION

In conclusion, our findings demonstrate significant differences in speckle-tracking echocardiography parameters in PHPT patients without known cardiovascular disease compared to healthy individuals. These results suggest that strain imaging may serve as an effective tool for early detection and risk stratification in PHPT. Larger, prospective research is required to verify these findings and further clarify the function of strain imaging in this patient population.

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Conflict of Interest: The authors declare there is no conflict of interest.

Informed Consent: Written informed consent was obtained from all patients included in the study.

Data Availability Statement: We recognize the importance of transparency and reproducibility in scientific research. However, to protect the privacy and confidentiality of the study participants, the raw data are not publicly available. Detailed descriptions of the study methodology and statistical analyses are provided in the manuscript to facilitate the reproducibility of the study. De-identified data may be made available by the corresponding author upon reasonable request, subject to applicable ethical and institutional regulations.

Ethical Approval: This study was approved by the Clinical Research Ethics Committee of Gaziantep University at its meeting dated February 5, 2020 under protocol code 52 and decision number 2020/52, and was conducted in accordance with the principles of the Declaration of Helsinki.

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Author Statement Regarding the Use of Artificial Intelligence-Enhanced Tools: If any artificial intelligence (AI) or AI-assisted tools (e.g., ChatGPT, Claude, Grammarly, DeepL) have been utilized during any stage of the research or manuscript preparation process, authors must formally disclose this information upon submission. Authors are required to specify the purpose of use (e.g., language editing, data analysis, code generation, literature review, or image creation) and the exact AI tool/model used (including version details).

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