JOURNAL OF CLINICAL MEDICINE OF KAZAKHSTAN (E-ISSN 2313-1519)
Original Article DOI: https://doi.org/10.23950/jcmk/13358

Delta parathormone value as an indicator of postoperative hypocalcemia in patients with parathyroid adenoma

Ramazan Topcu[1], Duygu Tutan[2], Bahadır Kartal[3], Murat Bulut Özkan[1], Fatih Şahin[1], Mehmet Berksun Tutan[1]

[1]*Department of General Surgery, Faculty of Medicine, Hitit University, Çorum, Turkey*
[2]*Department of Internal Medicine, Erol Olçok Training and Research Hospital, Çorum, Turkey*
[3]*Department of General Surgery, Erol Olçok Training and Research Hospital, Çorum, Turkey*

Received: 2023-04-24.
Accepted: 2023-05-23

J Clin Med Kaz 2023; 20(3):99-103

Corresponding author:
Duygu Tutan.
E-mail: duygus_781@hotmail.com;
ORCID: 0000-0003-0440-1146.

Abstract

Aim: In primary hyperparathyroidism patients, avoiding hypoparathyroidism and hypocalcemia after surgery is essential. We aimed to evaluate if the delta parathormone percent value (ΔPTH%) can identify patients with an increased risk of developing hypocalcemia after parathyroid surgery for primary hyperparathyroidism.

Material and methods: Eighty patients with parathyroid adenomas who underwent single parathyroidectomy were analyzed, and demographical data, preoperative, and postoperative laboratory data were collected were included in the study. Postoperative hypocalcemia was defined as a corrected calcium value below 8.5 mg/dL calculated from the blood values taken on the first postoperative day. The ΔPTH value was calculated by finding the difference between the preoperative PTH value and the postoperative PTH value, and the percentage of ΔPTH was calculated by dividing the ΔPTH value by the preoperative PTH (ΔPTH = Preoperative PTH – Postoperative PTH, and ΔPTH% = ΔPTH / Preoperative PTH).

Results: Postoperative hypocalcemia developed in 7.5% of the patients. Hypocalcemic patients had higher ΔPTH and ΔPTH% values. The selection of 130.95 ng/L as ΔPTH level cutoff level divided patients with and without postoperative hypocalcemia with 83.3% sensitivity and 62.2% specificity. As for ΔPTH%, a cut-off value of 71.4% had 100.0% sensitivity, 56.8% specificity, and a 16-fold increase in odds of postoperative hypocalcemia.

Conclusion: ΔPTH and ΔPTH% values are helpful predictors of postoperative hypocalcemia after parathyroidectomy and can be used as a guiding tool.

Key words: parathyroid adenoma, postoperative hypocalcemia, parathormone, endocrinology, complication

Introduction

A parathyroid adenoma is a benign tumor that develops in one of the four parathyroid glands. Parathyroid adenomas produce excessive parathyroid hormone (PTH), leading to primary hyperparathyroidism [1]. Hyperparathyroidism can cause various symptoms because of elevated calcium levels, including kidney stones, osteoporosis, fatigue, and depression. Hyperparathyroidism is more commonly diagnosed due to better diagnostic tools, more healthcare provider knowledge, and more widespread use of regular blood calcium tests [2].

The most definitive treatment for a parathyroid adenoma is the surgical removal of the affected gland, and one of the potential complications of parathyroidectomy is postoperative hypocalcemia [1]. In many cases, postoperative hypocalcemia has more than one cause. Reasons include direct damage to the parathyroid gland or inferior thyroid artery, accidental removal of other glands, hemodilution, hungry bone syndrome, and thyrotoxic osteodystrophy [3]. Long-term hypercalcemic suppression of non-adenomatous parathyroid tissue causes the remaining parathyroid tissue to be unable to respond when calcium levels must be abruptly controlled postoperatively [4]. During this time, a decline in serum calcium can be observed [5].

In parathyroid surgery, avoiding postoperative hypoparathyroidism and hypocalcemia is an essential principle. Significant postoperative morbidity is associated with symptomatic hypocalcemia in individuals receiving parathyroid surgery [6]. 15% to 30% of individuals with primary hyperparathyroidism have transient hypocalcemia after surgery [4, 6]. Most of the postoperative hypocalcemia occurrences are temporary, and just 0.5% to 3.8% of instances are found to be persistent [3].

According to many studies, a substantial decrease in calcium is not seen until the third and fourth postoperative days [6]. Because of this delay, an easily accessible perioperative approach for identifying individuals at risk for hypocalcemia would be advantageous [3]. Our initial objective in this study was to see whether the delta PTH percent value could be utilized to identify postoperative hypocalcemia.

Material and methods

All patients who underwent minimally invasive parathyroidectomy or unilateral parathyroidectomy due to a parathyroid adenoma at the Hitit University Erol Olçok Training and Research Hospital, Department of General Surgery, between 01.01.2017 - 01.10.2022, were found from the archives retrospectively. Patients over 18 years of age, patients without known hematological and oncological diseases, and patients with single parathyroid adenoma in radiologic images were found for the study. Then, patients with multiple parathyroid adenomas, patients with prior parathyroid or thyroid surgery, patients with known additional metabolic diseases, and patients whose pathology reports aren't consistent with an adenoma were excluded from the study. Patients who had parathyroidectomy for reasons apart from primary hyperparathyroidism (secondary and tertiary hyperparathyroidism, parathyroid malignancies) were also excluded from the study and 80 patients were selected for the study.

Age, gender, hospitalization duration, operation duration, preoperative lymphocyte, platelet, neutrophil, hemoglobin, albumin, calcium, parathormone values and postoperative 1st-day lymphocyte, platelet, neutrophil, hemoglobin, albumin, calcium values, and postoperative 1st-hour serum parathormone (PTH) values of 80 patients were recorded and included in the study. Adjusted calcium values were calculated by using patients' post-operative serum calcium and albumin levels. [AdjCa = (Ca + ((4 - Albumin) x 0.8)))]. Postoperative hypocalcemia was defined as a corrected calcium value below 8.5 mg/dL calculated from the blood values taken on the 1st postoperative day. The ΔPTH value was calculated by finding the difference between the preoperative PTH value and the postoperative PTH value, and the percentage of ΔPTH (ΔPTH%) was calculated by dividing the ΔPTH value by the preoperative PTH (ΔPTH = Preoperative PTH – Postoperative PTH, and ΔPTH% = ΔPTH / Preoperative PTH). This study has been approved by the local Clinical Research Ethics Committee (Decision No: 2023-38/ Date: 16.03.2023).

This study is planned retrospectively. All statistical analysis was performed using IBM SPSS Statistics for Windows software (version 26; IBM Corp., Armonk, N.Y., USA). Descriptive statistics were reported as count and percentages for categorical variables, and mean ± standard deviation and median in parentheses for numeric variables. The distribution of data was evaluated by the Shapiro-Wilks test. The relationships between the variables were investigated with the Pearson or Spearman correlation coefficient in accordance with the data distribution. A comparison of numerical measurements for two independent research groups for age, preoperative lymphocyte, platelet, hemoglobin, and postoperative platelet levels was done with student t-test, for hospitalization duration, operation duration, preoperative neutrophil, albumin, calcium, parathormone levels, postoperative lymphocyte, neutrophil, hemoglobin, albumin, calcium, corrected calcium levels, and post-operative 1st hour PTH levels, ΔPTH and ΔPTH percentage levels were evaluated by Mann Whitney U test in accordance with the data distribution. The ratio comparisons of the gender distribution according to the research groups were evaluated using a Chi-square test. A ROC analysis was done to differentiate groups with and without hypocalcemia, and the optimal cut-off values were found using the area under the curve and the Youden index. For these cut-off values, sensitivity, specificity, PPV, NPV, test accuracy, and odds ratio values were calculated. For odds ratio calculations, the Haldane-Anscombe correction technique was used for estimated odds ratios. For statistical significance, p<0.05 was accepted.

Results

The mean age of the 80 patients in the study was 58.58±11.02 (58.5) years, and 82.5% of the patients were female. The median length of hospital stay was 4 (3-8.75) days. The mean preoperative calcium level was 11.04±0.86 (11) mg/dL, and after parathyroidectomy, the mean postoperative calcium level was 9.42±0.83 (9.5) mg/dL. The adjusted postoperative calcium mean was 9.34±0.78 (9.31) mg/dL. Patient characteristics and other laboratory values are shown in Table 1.

The median preoperative parathormone level was 154.95 (104-244.75) pg/mL, and the postoperative first-hour parathormone median were found as 41.5 (25.78-69.35) pg/mL, there was a statistically significant decrease in parathormone levels after surgery (p<0.001). The median of the calculated ΔPTH values was 107.65 (70-193.65) pg/mL, and the mean of the ΔPTH% was 0.69±0.20 (0.71).

Comparison of patients with and without postoperative hypocalcemia

Post-operative hypocalcemia developed in 7.50% of the patients (Group 2). There were no statistically significant differences between groups in age, gender, hospitalization duration, and operation duration (p=0.213, p=0.281, p=0.342, p=0.216, respectively). There were no statistically significant differences between the mean preoperative lymphocyte, platelet, neutrophil counts and albumin, calcium levels of postoperative normocalcemic (Group 1) and hypocalcemic patients (Table 1).

The mean preoperative hemoglobin level of postoperative normocalcemic patients was significantly higher than patients with postoperative hypocalcemia (13.1±1.53 (13.05) vs 11.58±2.16 (11.9), p=0.027). Like the preoperative period, the mean of postoperative hemoglobin in normocalcemic patients was statistically significantly higher than in postoperative hypocalcemia patients (12.93±1.88 (13.1) vs 11.03±1.22 (10.7), p=0.012).

The median preoperative parathormone level of postoperative normocalcemic patients was 143.85 (103.75-238.38), and the median of preoperative hypocalcemic patients was 219.9 (146.5-1617), although the mean and median values were higher in the hypocalcemia group, no statistically significant difference was observed (p=0.139).

In an evaluation of postoperative laboratory values, there was no statistically significant difference between the mean of

Table 1 Comparison between patient groups

Variables		All Patients (n=80)	Postoperative Normocalcemia (n=74)	Postoperative Hypocalcemia (n=6)	Statistical Significance
Age		58.58±11.02 (58.5)	59.01±10.83 (59)	53.17±12.94 (50.5)	0.213
Gender	Male	14 (17.50%)	12 (16.22%)	2 (33.33%)	0.281
	Female	66 (82.50%)	62 (83.78%)	4 (66.67%)	
Hospitalization Duration*		4 (3-8.75)	4 (3-7.5)	7 (3.5-10.25)	0.342
Operation Duration*		78.5 (60-100)	75 (60-100)	90 (78.75-112.5)	0.216
Preoperative	Lymphocyte	2.11±0.68 (2.03)	2.13±0.68 (2.08)	1.89±0.69 (1.73)	0.414
	Platelet	266.83±75.15 (260)	262.64±66.42 (258.5)	318.5±146.12 (291.5)	0.394
	Neutrophil	4.21±1.51 (3.79)	4.23±1.54 (3.79)	3.91±1.06 (3.84)	0.777
	Hemoglobin	12.98±1.62 (13)	13.1±1.53 (13.05)	11.58±2.16 (11.9)	0.027
	Albumin	4.15±0.35 (4.2)	4.14±0.36 (4.2)	4.2±0.24 (4.2)	0.869
	Calcium	11.04±0.86 (11)	11.07±0.87 (11)	10.60±0.61 (10.6)	0.159
	Parathormone*	154.95 (104-244.75)	143.85 (103.75-238.38)	219.9 (146.5-1617)	0.139
Postoperative	Lymphocyte	2.23±0.95 (2.16)	2.26±0.97 (2.26)	1.83±0.46 (1.88)	0.195
	Platelet	271.45±73.15 (271.5)	270.86±72.88 (272)	278.67±83.16 (241.5)	0.803
	Neutrophil	5.05±2.35 (4.6)	5.12±2.39 (4.73)	4.18±1.58 (3.66)	0.261
	Hemoglobin	12.79±1.9 (12.95)	12.93±1.88 (13.1)	11.03±1.22 (10.7)	0.012
	Albumin	4.1±0.46 (4.2)	4.12±0.46 (4.2)	3.73±0.36 (3.75)	0.018
	Calcium	9.42±0.83 (9.5)	9.56±0.67 (9.5)	7.65±0.6 (7.95)	<0.001
	Parathormone*	41.5 (25.78-69.35)	42 (25.93-70.35)	31.85 (8.96-112.92)	0.401
	Corrected Calcium	9.34±0.78 (9.31)	9.46±0.67 (9.33)	7.86±0.61 (8.06)	<0.001
Post-operative Hypocalcemia	No hypocalcemia	74 (92.50%)			
	Post-operative hypocalcemia	6 (7.50%)			
ΔPTH*		107.65 (70-193.65)	95.75 (65.95-182.33)	187.99 (123.23-1363.58)	0.043
ΔPTH Percent		0.69±0.20 (0.71)	0.68±0.20 (0.70)	0.86±0.11 (0.87)	0.020

ΔPTH: Change in PTH level, *: Reported as median value and 25th and 75th percentiles

lymphocyte, platelet, and neutrophil counts between the two groups (Table 1). The mean postoperative albumin of patients in Group 1 was 4.12±0.46 (4.2), while it was 3.73±0.36 (3.75) in Group 2 (p<0.018). When the corrected calcium values of the two groups were compared, the corrected calcium mean of the postoperative normocalcemic patients was 9.46±0.67 (9.33), and the mean of postoperative hypocalcemia patients was 7.86±0.61 (8.06) (p<0.001).

There were no differences found between the groups in postoperative 1st-hour parathormone levels (42 (25.93-70.35) vs. 31.85 (8.96-112.92), p=0.401). When ΔPTH values were calculated, the median of Group 1 was 95.75 (65.95-182.33) and significantly lower than patients with postoperative hypocalcemia (187.99 (123.23-1363.58), p=0.043). The mean of ΔPTH% was significantly lower in postoperative normocalcemic patients than in the postoperative hypocalcemia group (0.68±0.20 (0.7) vs 0.86±0.11 (0.87), p=0.020).

Evaluation of ΔPTH and ΔPTH percentage as an indicator of postoperative hypocalcemia

To determine the optimal cut-off values of the ΔPTH value for the distinction of postoperative hypocalcemia, a ROC analysis was used (AUC 0.750 (0.091), CI%95 (0.571-0.929), p=0.043). The cut-off value for the ΔPTH was found to be 130.95 with 83.3% sensitivity, 62.2% specificity, 15.2% positive predictive value, 97.9% negative predictive value, and 63.8% test accuracy but when tested with Chi-square analysis there were no statistically significant differences observed and it was found unsuccessful as an independent indicator for postoperative hypocalcemia (OR 8.214, 95%CI 0.912-73.973, p=0.077).

In the ROC analysis for ΔPTH% (AUC 0.786 (0.076), CI95% (0.638-0.934), p=0.020), a value of 0.7140 (71.4%) was found with 100.0% sensitivity, 56.8% specificity, 15.8% positive predictive value, 100.0% negative predictive value, and 60.0% test accuracy (OR 17*, CI 95% 1.023-312.854*, p=0.009) (*: Haldane-Anscombe correction technique). When these diagnostic markers were compared, ΔPTH% was successful in predicting hypocalcemia. A patient whose parathormone level dropped by more than 71.4% at the first postoperative hour compared to the preoperative period was approximately 16 times more likely to belong to the hypocalcemia group than to other patients.

Discussion

Primary hyperparathyroidism has been recognized as a frequent endocrine condition due to its increased accidental diagnosis with regular laboratory testing. Early surgery is often the best course of action when treating parathyroid adenomas. However, one of the significant possible consequences of parathyroid surgery is postoperative hypocalcemia. Hypocalcemia may be either temporary or permanent. Increased risk of postoperative hypocalcemia is associated with the extent of exploration for parathyroidectomy [7]. Only individuals who received minimally invasive parathyroidectomy or unilateral parathyroidectomy were included in the present analysis to control this effect. In a prior meta-analysis, 1.6% of patients had postoperative hypocalcemia after targeted parathyroid investigation, and 13.2% had postoperative hypocalcemia after bilateral exploration [8]. In our study, this ratio was found as 7.5%.

Postoperative deterioration of the blood circulation of the parathyroid glands has also been suggested as one of the hypotheses for postoperative hypocalcemia to occur after bilateral total thyroidectomy and parathyroidectomy. Torer et al. found that secondary hyperparathyroidism patients with

Table 2 ΔPTH and ΔPTH Percent Possible Cut-off Values

Variables	Cut-Off	Diagnostic Values					ROC Analysis			Odds Ratio		
		Sensitivity	Specificity	PPV	NPV	Accuracy	AUC (SE)	%95 CI	p	OR	%95 CI	p
ΔPTH	130.95	83.3%	62.2%	15.2%	97.9%	63.75%	0.750 (0.091)	0.571-0.929	0.043	8.214	0.912-73.973	0.077
ΔPTH Percent	55.08%	100%	24.3%	9.7%	100%	30%	0.786 (0.076)	0.638-0.934	0.02	4.256*	0.228-79.241*	0.328
	85.28%	50%	75.7%	14.3%	94.9%	73.75%				3.111	0.576-16.795	0.182
	71.40%	100%	56.8%	15.8%	100%	60%				17*	1.023-312.854*	0.009

Values are calculated and estimated based on Haldane-Anscombe correction, PPV: positive predictive value, NPV: negative predictive value, ROC: receiver operating curve, AUC: area under curve, SE: standard error, CI: confidence interval, p: statistical significance, OR: odds ratio

postoperative hypocalcemia after parathyroidectomy had lower preoperative hemoglobin levels than patients without postoperative hypocalcemia [9]. In our study, we found that both preoperative and postoperative hemoglobin levels of patients with postoperative hypocalcemia were lower than those of other patients. The fact that such a difference was observed between the hemoglobin levels of the two groups in our study could indicate the importance of circulation in the pathogenesis of hypocalcemia after parathyroidectomy.

There was no statistically significant difference between the albumin levels among the patient groups in our study in the preoperative period, but the postoperative albumin levels of the patients with hypocalcemia were significantly lower than the other group. Hemodilution was considered as the reason for the difference in such a short time. A study conducted with patients after total thyroidectomy by Karunakaran et al. observed that the intraoperative fluid volume given was higher in the group with postoperative hypocalcemia [10]. While we did not have the opportunity to monitor intraoperative fluid administration in our study directly, we believe the difference in albumin levels after surgery could be caused by the difference in intraoperative fluid volume given and might be a factor for postoperative hypocalcemia.

In a study conducted by Abdullah et al. on patients after total thyroidectomy, they predicted that the level of parathormone in the early postoperative period alone might be a marker for postoperative hypocalcemia [11]. Similarly, AlQahtani et al. suggested that the postoperative first-hour parathormone level after bilateral total thyroidectomy alone can predict postoperative hypocalcemia [12]. However, in our study, both preoperative and postoperative parathormone levels did not differ significantly between the two groups and could not be used as a single predictor for predicting postoperative hypocalcemia after single parathyroidectomy.

In some studies to predict hypocalcemia after bilateral total thyroidectomy, some authors have found success with a single parathormone measurement [11]. As in our study, studies examining the difference between preoperative and postoperative parathormone levels also report successful results [13, 14]. In a study by Noordzij et al., the percentage of PTH decline in the postoperative 6th hour was successful in predicting postoperative hypocalcemia with a cut-off value of %65 [15]. Chapman et al. reported the optimal cut-off value for 6th-hour parathormone drop lower than Noordzij, at %44 [16]. In another study by Soylu et al., more than a %40.8 decrease in 2nd-hour parathormone levels was predictive of postoperative hypocalcemia after bilateral total thyroidectomy [13]. A study done by Vanderlei et al. was also using the percentage of change between preoperative and postoperative first-hour parathormone levels similar to our study; the authors demonstrated that a 73.5% PTH drop in the first hour after bilateral total thyroidectomy has a sensitivity of 91.6% and a specificity of 87.5% for predicting postoperative hypocalcemia [17]. In our patient population of primary hyperparathyroidism patients, we found a PTH change of more than 71.4 percent was prognostic for postoperative hypocalcemia with a 100% sensitivity and 56.8% specificity. The fact that the sensitivity was calculated as high as 100% may be due to the small number of postoperative hypocalcemia patients in our study. A patient whose parathormone level dropped by more than 71.4% at the first postoperative hour was approximately 16 times more likely to belong to the hypocalcemia group than to other patients.

According to some studies, calcium and vitamin D supplementation are recommended to all patients after total thyroidectomy. Unfortunately, this strategy causes at least fifty percent of patients to get needless care, which raises healthcare costs [18]. With a more objective assessment of the risk of hypocalcemia, unnecessary treatment and the economic burden it brings can be avoided. As a cheap and easily reproducible way of determining the risk of postoperative hypocalcemia after parathyroidectomy, the ΔPTH% value calculated from preoperative and first-hour parathormone values is a promising tool that can be beneficial to clinicians.

The main limitations of this research were its retrospective approach, relatively small sample size, and absence of intraoperative fluid intake data. Even though there are many studies investigating postoperative hypocalcemia incidence and risk factors after total thyroidectomy, to our knowledge, this study is one of the first studies using parathormone change percentage (ΔPTH%) for predicting postoperative hypocalcemia in patients operated for primary hyperparathyroidism caused by parathyroid adenomas.

Determining the risk of postoperative hypocalcemia following parathyroidectomy in the first few hours after surgery might help avoid a common complication arising from an early hospital release. While preoperative and postoperative parathormone levels could not predict postoperative hypocalcemia after parathyroidectomy for parathyroid adenomas alone, ΔPTH and ΔPTH% are helpful in this prediction. Patients at risk for postoperative hypocalcemia may be recognized and treated sooner using this parameter, leading to decreased morbidity. Larger series from prospective, randomized, multicenter trials are required to prove the relationship between anemia, intraoperative fluid volume, ΔPTH, ΔPTH%, and postoperative hypocalcemia.

Ethics Committee Approval: Hitit University Faculty of Medicine Clinical Researches Ethics Committee granted approval for this study (Decision No: 2023-38/Date: 16.03.2023).

Disclosures: There is no conflict of interest for all authors.

Acknowledgements: None.

Funding: None.

References

1. Silverberg SJ, Fuleihan GE-H. Primary hyperparathyroidism: Management - UpToDate 2022 [updated 2023/03/05]. Available from: https://www.uptodate.com/contents/primary-hyperparathyroidism-management.
2. Grosso I, Sargiotto A, D'Amelio P, Tamone C, Gasparri G, De Filippi PG, et al. Preoperative localization of parathyroid adenoma with sonography and 99mTc-sestamibi scintigraphy in primary hyperparathyroidism. *J Clin Ultrasound.* 2007;35(4):186-190. https://doi.org/10.1002/jcu.20319
3. McLeod IK, Arciero C, Noordzij JP, Stojadinovic A, Peoples G, Melder PC, et al. The use of rapid parathyroid hormone assay in predicting postoperative hypocalcemia after total or completion thyroidectomy. *Thyroid*. 2006;16(3):259-265. https://doi.org/10.1089/thy.2006.16.259
4. Brasier AR, Nussbaum SR. Hungry bone syndrome: clinical and biochemical predictors of its occurrence after parathyroid surgery. *Am J Med*. 1988;84(4):654-660. https://doi.org/10.1016/0002-9343(88)90100-3
5. Ferrer-Ramirez MJ, Arroyo Domingo M, Lopez-Molla C, Sola Izquierdo E, Garzon Pastor S, Morillas Arino C, et al. Transient rise in intact parathyroid hormone concentration after surgery for parathyroid adenoma. *Otolaryngol Head Neck Surg.* 2003;128(6):771-776. https://doi.org/10.1016/S0194-59980300088-3
6. Westerdahl J, Lindblom P, Valdemarsson S, Tibblin S, Bergenfelz A. Risk factors for postoperative hypocalcemia after surgery for primary hyperparathyroidism. *Arch Surg.* 2000;135(2):142-147. https://doi.org/10.1001/archsurg.135.2.142
7. Karamanakos SN, Markou KB, Panagopoulos K, Karavias D, Vagianos CE, Scopa CD, et al. Complications and risk factors related to the extent of surgery in thyroidectomy. Results from 2,043 procedures. *Hormones (Athens)*. 2010;9(4):318-325. https://doi.org/10.14310/horm.2002.1283
8. Jinih M, O'Connell E, O'Leary DP, Liew A, Redmond HP. Focused Versus Bilateral Parathyroid Exploration for Primary Hyperparathyroidism: A Systematic Review and Meta-analysis. *Ann Surg Oncol*. 2017;24(7):1924-1934. https://doi.org/10.1245/s10434-016-5694-1
9. Torer N, Torun D, Torer N, Micozkadioglu H, Noyan T, Ozdemir FN, et al. Predictors of early postoperative hypocalcemia in hemodialysis patients with secondary hyperparathyroidism. *Transplant Proc.* 2009;41(9):3642-3646. https://doi.org/10.1016/j.transproceed.2009.06.207
10. Karunakaran P, Abraham DT, Devadas G, Ramalingam S, Balu S, Hussain Z. The impact of operative duration and intraoperative fluid dynamics on postoperative hypocalcemia after total thyroidectomy: a prospective non-randomized study. *Langenbecks Arch Surg.* 2021;406(4):1211-1221. https://doi.org/10.1007/s00423-020-02013-8
11. Abdullah AS. The role of early postoperative parathyroid hormone level after total thyroidectomy in prediction of hypocalcemia. *Ann Med Surg (Lond).* 2021;65:102252. https://doi.org/10.1016/j.amsu.2021.102252
12. AlQahtani A, Parsyan A, Payne R, Tabah R. Parathyroid hormone levels 1 hour after thyroidectomy: an early predictor of postoperative hypocalcemia. Can J Surg. 2014;57(4):237-240. https://doi.org/10.1503/cjs.008013
13. Soylu S, Teksoz S. Earlier Prediction of Hypocalcemia by Postoperative Second Hour Parathyroid Hormone Level After Total Thyroidectomy. *Acta Endocrinol (Buchar).* 2020;16(2):250-255. https://doi.org/10.4183/aeb.2020.250
14. Sormaz IC, Iscan AY, Ozgur I, Karakus S, Tunca F, Senyurek YG, et al. The Impact of Postoperative Percent Change of Parathormone Level From Baseline Value on the Rate of Hypocalcemia After Total Thyroidectomy. *International Surgery.* 2017;105(1-3):291-299. https://doi.org/10.9738/intsurg-d-16-00249.1
15. Noordzij JP, Lee SL, Bernet VJ, Payne RJ, Cohen SM, McLeod IK, et al. Early prediction of hypocalcemia after thyroidectomy using parathyroid hormone: an analysis of pooled individual patient data from nine observational studies. *J Am Coll Surg.* 2007;205(6):748-754. https://doi.org/10.1016/j.jamcollsurg.2007.06.298
16. Chapman DB, French CC, Leng X, Browne JD, Waltonen JD, Sullivan CA. Parathyroid hormone early percent change: an individualized approach to predict postthyroidectomy hypocalcemia. *Am J Otolaryngol.* 2012;33(2):216-220. https://doi.org/10.1016/j.amjoto.2011.06.004
17. Vanderlei FA, Vieira JG, Hojaij FC, Cervantes O, Kunii IS, Ohe MN, et al. Parathyroid hormone: an early predictor of symptomatic hypocalcemia after total thyroidectomy. *Arq Bras Endocrinol Metabol.* 2012;56(3):168-172. https://doi.org/10.1590/s0004-27302012000300003
18. Zambudio AR, Rodríguez J, Riquelme J, Soria T, Canteras M, Parrilla P. Prospective study of postoperative complications after total thyroidectomy for multinodular goiters by surgeons with experience in endocrine surgery. *Ann Surg.* 2004;240(1):18-25. https://doi.org/10.1097/01.sla.0000129357.58265.3c