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The impact of thyroid function on surgical prognosis in patients undergoing cardiac and major vascular surgeries

Qi Sun[1†], Wei Wang[2†], Xiaoming Mao[2*] and Hao Liu[2*]

Abstract

Objective This study aims to elucidate the relationship between thyroid function and surgical prognosis in patients undergoing cardiac and major vascular surgeries.

Methods A retrospective cohort study was conducted on patients undergoing cardiac or major vascular surgeries. Preoperative thyroid function tests, including TSH, free T3, and free T4 levels, as well as postoperative thyroid function tests, were assessed. Key postoperative outcomes, such as total hospital stay, postoperative hospital stay, ICU stay, and duration of mechanical ventilation, were recorded and analyzed. The analytical approach included Pearson correlation, multivariable logistic regression models, and restricted cubic splines.

Results This study analyzed a cohort of 472 patients who underwent various cardiovascular surgeries, including coronary artery bypass grafting (173 patients), aortic surgery (131 patients), valve surgery (125 patients), and primary cardiac neoplasms resection (43 patients). Significant changes in thyroid hormone levels were observed preoperatively and postoperatively, with TSH, FT3, and FT4 levels showing a significant decrease from preoperative values ($p < 0.001$). Multivariate logistic regression analysis further revealed that ΔTSH is significantly associated with total hospital stay, postoperative hospital stay, and duration of mechanical ventilation; postoperative FT3 levels were significantly inversely related to total hospital stay, ICU stay, and ventilator requirements. Additionally, although no significant nonlinear relationships were found (all $p > 0.05$).

Conclusions Thyroid dysfunction may impact postoperative outcomes in cardiac and major vascular surgery patients.

Keywords Thyroid function, Cardiac surgery, Major vascular surgery, Outcome

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Introduction

Cardiac and major vascular surgeries are among the most complex and high-risk procedures in modern medicine, often associated with significant morbidity and mortality [1–3]. These surgeries require meticulous preoperative planning, intraoperative precision, and comprehensive postoperative care to improve outcomes. Although surgical techniques and perioperative management have advanced significantly, the incidence of adverse events remains a significant concern. Therefore, understanding the factors that influence postoperative outcomes is crucial for improving patient care and prognosis.

One such factor that has garnered increasing attention is thyroid dysfunction. Thyroid hormones play a crucial role in regulating various physiological processes, including metabolism, cardiovascular function, and overall systemic homeostasis [4, 5]. These hormones are integral to the proper functioning of multiple organ systems, ensuring that metabolic rates are optimized and cardiovascular operations are stable. Recent research has highlighted the significance of preoperative thyroid function assessment as a predictor of surgical risk. Studies have shown that both overt and subclinical thyroid dysfunction are linked to an increased incidence of adverse events, including arrhythmias, myocardial infarction, and extended hospital stays post-surgery [6–9]. For example, Park et al. reported that patients with hypothyroidism undergoing cardiac surgery were more likely to develop postoperative atrial fibrillation and heart failure compared to euthyroid patients [10]. Similarly, hyperthyroidism is also associated with increased perioperative risks, such as tachyarrhythmias and hemodynamic instability. Patients with untreated or poorly controlled hyperthyroidism are at a higher risk of developing significant cardiovascular complications during surgery [11]. In the perioperative period, the stress of surgery can exacerbate thyrotoxic symptoms, increasing the risk of a thyroid storm [12]. Hemodynamic instability in hyperthyroid patients typically results from increased cardiac output, decreased systemic vascular resistance, and enhanced sensitivity to catecholamines, which complicates anesthesia and surgical management [12].

However, there is a paucity of comprehensive data examining this relationship in the context of cardiac and major vascular surgeries. This study aims to investigate the association between thyroid function (including preoperative, postoperative, and preoperative-to-postoperative changes) and surgical outcomes, offering valuable thyroid-related insights for improving the prognosis of patients undergoing these high-risk surgeries.

Methods and materials

Study design

The study included patients from January 2020 to January 2024 at Nanjing First Hospital. The inclusion criteria were as follows: (1) Adults between 18 and 75 years of age; (2) Patients scheduled for elective cardiac or major vascular surgery. The exclusion criteria were as follows: (1) Off-pump coronary surgery; (2) Patients with a history of thyroid cancer or undergoing treatment for thyroid cancer; (3) Patients with severe systemic illness or conditions such as advanced renal or hepatic failure; (4) Pregnant or breastfeeding women; (5) Patients unable or unwilling to comply with the study protocol or follow-up requirements; (6) Patients who underwent major surgery within the 30 days prior to the study. All cardiac and major vascular surgeries were performed by experienced surgeons. As this was a retrospective study, informed consent was waived. Patient data confidentiality was strictly maintained throughout the study, in accordance with ethical guidelines and regulations.

Clinical and laboratory assessments

The data were extracted from electronic medical records and included demographic information, type of surgery, and preoperative and postoperative thyroid function test results. We assessed thyroid function 3 to 5 days prior to surgery, primarily focusing on free triiodothyronine (FT3), free thyroxine (FT4), and thyroid-stimulating hormone (TSH) levels. Additionally, thyroid hormone levels were monitored on the second postoperative day. FT3, FT4, and TSH levels were measured using a chemiluminescence assay on the Abbott Laboratories platform. The standard reference ranges for FT4, FT3, and TSH in our hospital's laboratory are 9.0–19.0 pmol/L, 2.63–5.7 pmol/L, and 0.35–4.94 mIU/L, respectively. Postoperative outcomes were recorded, focusing on the following categories: (1) Length of stay: total hospital stay, post-hospital discharge stay, ICU stay; (2) Clinical conditions: postoperative constipation, postoperative drowsiness, mediastinal drainage, total diversion volume; (3) Pharmacological interventions: norepinephrine, dopamine, epinephrine; (4) Clinical complications: in-patient mortality, duration of mechanical ventilation, low cardiac output, arrhythmias, re-intubation, or noninvasive mechanical ventilation.

Statistical analysis

Statistical analysis was performed using SPSS software version 26.0. Continuous variables were expressed as mean ± standard deviation (SD) and compared using either the ANOVA test for normally distributed data or the Kruskal-Wallis test for non-normally distributed data. Categorical variables were expressed as frequencies and percentages. Comparisons were made using the

Chi-square test or Fisher's exact test, depending on the sample size. The paired t-test was used to compare preoperative and postoperative thyroid function changes. Pearson correlation analysis was used to explore the relationship between thyroid function and postoperative outcomes. Multivariate logistic regression analyses were conducted to assess the impact of thyroid function on various postoperative outcomes. Restricted cubic spline (RCS) analysis was used to investigate the nonlinear relationship between thyroid function and postoperative outcomes. A two-tailed p-value of <0.05 was considered statistically significant.

Results

Patient characteristics

The study analyzed a cohort of 472 patients who underwent various types of cardiac surgeries, including coronary artery bypass grafting (CABG), aortic surgery, valve surgery, and resection of primary cardiac neoplasms. The distribution of patients according to surgery type was as follows: CABG (173 patients), aortic surgery (131 patients), valve surgery (125 patients), and primary cardiac neoplasms resection (43 patients). The results showed that preoperative FT3 levels were higher in the aortic surgery group than in the other groups ($p=0.039$), while preoperative FT4 levels were higher in the valve surgery group ($p=0.038$). Postoperative FT4 levels were higher in the CABG group ($p=0.002$), and postoperative EF was higher in the primary cardiac neoplasms resection group ($p<0.001$). Recovery times differed among the groups, with the primary cardiac neoplasms resection group having a shorter total hospital stay ($p=0.001$) and the valve surgery group having a shorter ICU stay ($p<0.001$). Regarding postoperative complications, the aortic surgery group had a higher degree of postoperative somnolence ($p=0.018$), while the CABG group had a higher total drainage volume ($p=0.019$). Detailed information is provided in Table 1.

Preoperative and postoperative thyroid function in cardiac and major vascular surgeries

Postoperative measurements showed significant reductions in TSH, FT3, and FT4 levels compared to preoperative values. Specifically, TSH decreased from 2.61 ± 2.07 to 1.12 ± 1.53, FT3 from 3.81 ± 0.96 to 2.45 ± 0.66, and FT4 from 13.04 ± 1.88 to 11.98 ± 2.57. These changes were statistically significant, with p-values <0.001 for all comparisons, indicating a substantial impact of the surgical intervention on thyroid function (see Table 2).

Table 1 Patient characteristics following different cardiac and major vascular surgeries

	ALL (472)	CABG (173)	AS (131)	VS (125)	PCNR (43)	F-value	*p* value
Pre-TSH, mIU/L	2.61 ± 2.07	2.69 ± 2.18	2.49 ± 1.65	2.84 ± 2.47	1.98 ± 1.28	2.084	0.101
Pre-FT3, pmol/L	3.81 ± 0.96	3.76 ± 0.9	4.01 ± 1.08	3.71 ± 0.95	3.65 ± 0.77	2.82	0.039
Pre- FT4, pmol/L	13.04 ± 1.88	12.75 ± 1.49	13.11 ± 1.84	13.37 ± 2.36	13.02 ± 1.69	2.825	0.038
Post-TSH, mIU/L	1.12 ± 1.53	1.21 ± 1.97	1.04 ± 1.11	1.05 ± 1.32	1.18 ± 1.13	0.429	0.733
Post-FT3, pmol/L	2.45 ± 0.66	2.42 ± 0.59	2.57 ± 0.64	2.4 ± 0.6	2.39 ± 1.06	1.95	0.121
Post-FT4, pmol/L	11.98 ± 2.57	12.15 ± 2.23	12.21 ± 2.38	11.99 ± 2.45	10.54 ± 4.04	5.191	0.002
Pre-EF, %	58.72 ± 7.77	58.1 ± 8.51	58.49 ± 8.42	58.82 ± 6.48	61.65 ± 5.14	2.478	0.061
Post-EF, %	57.67 ± 9.43	55.54 ± 11.57	59.58 ± 7.7	57.48 ± 8.01	61.02 ± 5.71	6.773	< 0.001
ΔTSH, mIU/L	1.49 ± 1.77	1.48 ± 1.99	1.45 ± 1.27	1.79 ± 2.01	0.8 ± 1.12	3.407	0.018
ΔFT3, pmol/L	1.35 ± 0.92	1.34 ± 0.88	1.44 ± 1.03	1.32 ± 0.84	1.27 ± 0.94	0.571	0.634
ΔFT4, pmol/L	1.06 ± 2.5	0.6 ± 2.14	0.9 ± 2.15	1.39 ± 2.49	2.48 ± 3.9	7.797	< 0.001
ΔEF, %	1.05 ± 5.39	2.55 ± 5.66	-1.04 ± 4.97	1.3 ± 4.9	0.63 ± 4.82	11.979	< 0.001
Total hospital stay, day	19.02 ± 8.33	20.21 ± 10.31	18.92 ± 7.33	19.05 ± 6.29	14.49 ± 5.7	5.579	0.001
Post-hospital stay, day	13.74 ± 6.39	13.82 ± 6.36	15.24 ± 7.42	13.22 ± 5.33	10.33 ± 4.3	7.02	< 0.001
ICU stay, day	2.54 ± 2.97	2.51 ± 2.86	3.34 ± 4.09	2.14 ± 1.78	1.33 ± 0.68	6.489	< 0.001
Duration of mechanical ventilation, hour	19.29 ± 31.76	15.27 ± 18.51	27.39 ± 44.52	18.67 ± 33.61	12.65 ± 10.95	4.506	0.004
Norepinephrine, IU	1.63 ± 2.19	1.69 ± 2.64	1.77 ± 2.06	1.31 ± 1.44	1.93 ± 2.42	1.369	0.252
Dopamine, IU	3.46 ± 3.08	3.33 ± 2.94	3.68 ± 3.13	3.54 ± 2.88	3.07 ± 3.99	0.58	0.628
Epinephrine, IU	1.03 ± 2.06	1.13 ± 2.43	0.97 ± 1.79	1.07 ± 1.88	0.7 ± 1.68	0.57	0.635
Million, IU	0.86 ± 1.69	0.66 ± 1.37	0.8 ± 1.89	1.1 ± 1.7	1.12 ± 2.07	2.086	0.101
Postoperative constipation, level	1.32 ± 1.09	1.29 ± 1.07	1.42 ± 1.15	1.39 ± 1.05	0.93 ± 1.01	2.445	0.063
Postoperative drowsiness, level	1.33 ± 1.11	1.35 ± 1.07	1.44 ± 1.18	1.38 ± 1.08	0.84 ± 1.04	3.404	0.018
Mediastinal drainage, ml	371.03 ± 423.61	453.61 ± 323.94	383.43 ± 601.44	285.96 ± 344.22	248.26 ± 218.22	5.252	0.001
Total diversion volume, ml	387.18 ± 430.73	457.18 ± 325.4	391.4 ± 607.17	304.81 ± 366.49	332.09 ± 256.33	3.335	0.019

Pre: Preoperative; Post: Postoperative; Δ: Change; CABG: Coronary artery bypass grafting; AS: Aortic surgery; VS: Valve surgery; PCNR: Primary cardiac neoplasms resection; TSH: Thyroid-stimulating hormone; FT3: Free triiodothyronine; FT4: Free thyroxine; EF: Ejection fraction

Table 2 Thyroid function before and after surgery

		Mean ± SD	t value	*p* value
TSH	**Preoperative**	2.61 ± 2.07	32.044	< 0.001
	Postoperative	1.12 ± 1.53		
FT3	**Preoperative**	3.81 ± 0.96	9.249	< 0.001
	Postoperative	2.45 ± 0.66		
FT4	**Preoperative**	13.04 ± 1.88	18.263	< 0.001
	Postoperative	11.98 ± 2.57		

Table 3 Multivariate linear regression analysis for thyroid function and postoperative outcomes

Dependent Variable	Independent Variable	Standardized beta	t	*p* value
Total hospital stay	ΔTSH	0.152	3.376	0.001
	Surgical method	-0.151	-3.380	0.001
	Post-FT3	-0.129	-2.870	0.004
Post-hospital stay	ΔTSH	0.188	4.258	0.000
	ΔFT3	0.157	3.436	0.001
	Surgical method	-0.119	-2.711	0.007
	Post-FT3	-0.110	-2.386	0.017
ICU stay	Post-FT3	-0.168	-3.617	0.000
	Pre-TSH	0.144	3.246	0.001
	Surgical method	-0.103	-2.327	0.020
	ΔFT3	0.106	2.282	0.023
Duration of mechanical ventilation	Post-FT3	-0.171	-3.603	0.000
	ΔFT3	0.097	1.956	0.050
	ΔTSH	0.136	3.021	0.003
	Pre-FT4	0.115	2.396	0.017

Pre: Preoperative; Post: Postoperative; Δ: Change;

Association between thyroid function and cardiovascular postoperative outcomes

First, we performed a correlation analysis using the Pearson test. The results indicated that preoperative TSH levels and changes in TSH levels were positively correlated with total hospital stay, ICU stay, and the use of mechanical ventilation and dopamine. In contrast, postoperative FT3 levels were negatively correlated with these variables, suggesting that higher FT3 levels are associated with shorter hospital stays and reduced need for intensive care. Postoperative FT4 levels were primarily associated with reduced use of certain medications. For details, please refer to Supplementary Table 1.

We also performed multivariate logistic regression analysis on the four main outcomes: total hospital stay, postoperative hospital stay, ICU stay, and duration of mechanical ventilation. The surgical method, preoperative and postoperative TSH, FT3, FT4, EF, and preoperative-postoperative changes in TSH, FT3, and FT4 were included in the regression model. The results showed significant associations between thyroid function parameters (both preoperative and postoperative) and various postoperative outcomes. Change in TSH (ΔTSH) was significantly associated with total hospital stay (beta = 0.152, $p = 0.001$), postoperative hospital stay (beta = 0.188, $p < 0.001$), and duration of mechanical ventilation (beta = 0.136, $p = 0.003$). Postoperative FT3 was inversely associated with total hospital stay (beta = -0.129, $p = 0.004$), ICU stay (beta = -0.168, $p < 0.001$), and duration of mechanical ventilation (beta = -0.171, $p < 0.001$). Additionally, the surgical method was significantly associated with shorter total hospital stay (beta = -0.151, $p = 0.001$), postoperative hospital stay (beta = -0.119, $p = 0.007$), and ICU stay (beta = -0.103, $p = 0.020$). For details, please refer to Table 3.

The detection of nonlinear relationships

To determine the appropriate range of preoperative thyroid function control, we performed RCS analysis. This analysis explored the nonlinear associations between preoperative thyroid function and total hospital stay, postoperative hospital stay, ICU days, and duration of mechanical ventilation. Using a nonlinear regression model with four knots, the results show significant correlations between Pre-TSH and total hospital stay, ICU stay, and, most notably, duration of mechanical ventilation ($p < 0.001$). In contrast, Pre-FT3 and Pre-FT4 showed weak or no correlations with clinical outcomes, with most p-values exceeding 0.05, indicating a lack of statistically significant associations with hospital-related outcomes. Although no significant nonlinear relationships were found (all $p > 0.05$), some results exhibited nonlinear tendencies. Nonlinear tendencies between Pre-FT3 and total hospital stay, as well as ICU stay, were observed, as illustrated in Fig. 1 and detailed in Supplementary Table 2.

Discussion

This study highlights the potential impact of thyroid hormone levels on postoperative outcomes. Elevated preoperative TSH levels and changes in TSH were associated with longer hospital stays, prolonged ICU stays, and extended durations of mechanical ventilation, indicating poorer recovery. In contrast, higher postoperative FT3 levels correlated with shorter hospital stays, reduced ICU stays, and decreased ventilator dependency, suggesting a protective effect. RCS analysis further confirmed the significant correlation between preoperative TSH and major postoperative outcomes. These findings underscore the importance of monitoring and managing thyroid function both pre- and post-surgery to optimize patient recovery.

Previous studies have highlighted the importance of maintaining thyroid function in improving the prognosis of major surgeries. Baysal et al. demonstrated that preoperative and postoperative thyroid hormone levels were

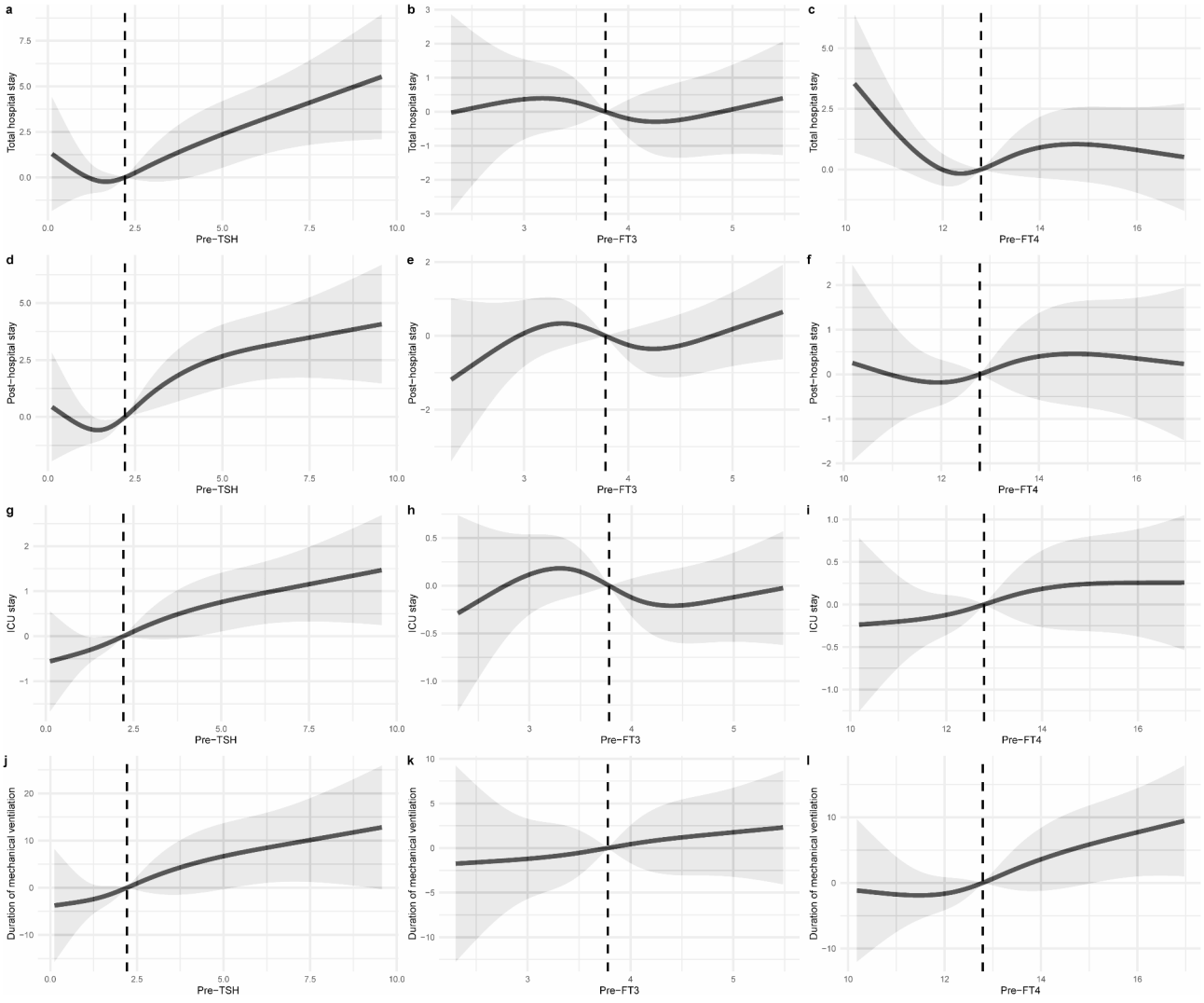

Fig. 1 The nonlinear association between preoperative thyroid function and postoperative outcomes

associated with low cardiac output syndrome in pediatric patients, emphasizing the need to optimize thyroid function [13]. Similarly, Gurcu et al. reported that lower postoperative FT3 and FT4 levels were linked to poorer outcomes in children undergoing cardiac surgery, aligning with our finding that higher FT3 levels have a protective effect [14]. During and after cardiopulmonary bypass surgery, there is a transient decrease in serum T3 concentrations, which may lead to postoperative hemodynamic issues [15]. Euthyroid-sick syndrome (ESS) is a common transient thyroid dysfunction characterized by a lack of significant changes in thyroid function in the short term but with typical thyroid hormone imbalances. ESS often occurs following surgery or severe illness, and its changes may be closely related to poor postoperative outcomes. Specifically, postoperative ESS is closely associated with prolonged hospital stay, increased postoperative complication rates, and higher mortality. Fliers and McIver et al. suggested that ESS may be related to postoperative dysregulation of the endocrine system, immune system responses, and metabolic abnormalities [16, 17]. These physiological changes may further exacerbate postoperative recovery difficulties by affecting cardiovascular, metabolic, and immune functions. Although clinical experience suggests that supplemental T3 improves outcomes after cardiopulmonary bypass surgery [18, 19], related clinical trials have failed to demonstrate its benefits adequately [20–22]. For example, a systematic review found that although postoperative T3 therapy increased cardiac output, it did not significantly affect mortality [23]. Furthermore, a trial included in the systematic review involved 142 patients with coronary artery disease undergoing CABG, who were randomly assigned to receive intravenous T3 (0.8 mcg/kg loading dose, followed by an infusion of 0.113 mcg/kg/hour for six hours) or a placebo after surgery [24]. Compared to the placebo

group, the T3 group had a higher average cardiac index and lower systemic vascular resistance, but there was no difference in the incidence of arrhythmias, the need for inotropic agents or vasodilators, or perioperative morbidity and mortality within 24 h after surgery. Subsequent randomized controlled trials using oral T3 (20 mcg every 12 h) also failed to show clinical benefits [25].Nevertheless, Vacante et al.'s study showed that appropriate hormone replacement therapy for hypothyroid patients can effectively reduce postoperative complications, especially in high-risk surgeries [7, 26]. While there is ongoing debate regarding thyroid hormone supplementation, existing studies consistently highlight the key role of thyroid hormone monitoring in the management of cardiac and major vascular surgeries. Preoperative screening for elevated TSH and postoperative monitoring of FT3 levels help guide targeted interventions, thus promoting patient recovery. Our findings further confirm the importance of thyroid hormone levels, especially TSH, in the postoperative recovery process.

The observed mechanisms likely involve multiple pathophysiological processes. Thyroid dysfunction can affect hemodynamics, endothelial function, and coagulation pathways, increasing the risk of perioperative complications in cardiac and major vascular surgery. In hypothyroid patients, reduced thyroid hormone levels lead to decreased cardiac output and increased systemic vascular resistance, resulting in impaired tissue perfusion and oxygen delivery—critical factors during and after surgery [27]. Conversely, hyperthyroidism elevates cardiac output and heart rate, increasing myocardial oxygen consumption and heightening the risk of ischemia, particularly in patients with underlying cardiovascular diseases [27]. Low thyroid hormone levels impair myocardial contractility, leading to bradycardia and decreased stroke volume, which can prolong recovery times and elevate the risk of perioperative cardiac events [28]. Although elevated thyroid hormone levels enhance myocardial contractility, they also cause tachycardia and increase the risk of arrhythmias [28]. Thyroid hormone deficiency further contributes to endothelial dysfunction by reducing nitric oxide production, a vital regulator of vascular tone. This may promote atherosclerosis, increase vascular stiffness, and exacerbate perioperative complications [29]. While hyperthyroidism may initially improve endothelial function by increasing nitric oxide production, chronic hyperthyroid states can lead to endothelial injury and dysfunction, raising the risk of thromboembolic events [29]. Additionally, hyperthyroidism is associated with a pro-thrombotic state characterized by elevated fibrinogen levels and reduced fibrinolysis, increasing the risk of venous thromboembolism and clotting complications during the perioperative period [30]. Patients with hypothyroidism or subclinical hypothyroidism also exhibit a lower basal metabolic rate, making them more prone to hypothermia during surgery and delaying postoperative recovery [31].

Overall, these findings hold certain clinical significance for the perioperative management of patients with thyroid dysfunction, suggesting the necessity of preoperative thyroid function screening for those undergoing cardiac and major vascular surgery. However, this study has several limitations. First, the retrospective design may introduce selection bias, which limits the ability to establish causal relationships. Second, potential confounding factors, such as intraoperative medications (e.g., high-dose corticosteroids, dopamine, nonsteroidal anti-inflammatory drugs, heparin), inflammation, and preoperative angiography, were not fully controlled, underscoring the need for further prospective studies. Additionally, the study participants were predominantly from the Chinese population, which may limit the generalizability of the findings to other populations. Therefore, future prospective studies should aim to include larger, more diverse populations to validate and strengthen these results.

Conclusions

In conclusion, thyroid dysfunction may have an impact on postoperative outcomes in patients undergoing cardiac and major vascular surgeries. These findings highlight the potential value of preoperative thyroid assessment and individualized management strategies in optimizing surgical recovery.

Supplementary Information

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Supplementary Material 1

Author contributions

All authors were involved in the study conception and design, and analysis and interpretation of the data; all authors contributed to drafting and revising the paper critically for intellectual content, gave their final approval of the version to be published and have agreed to be held accountable for all aspects of the work.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Competing interests
The authors declare no competing interests.

Declaration of competing interest
The authors declare that there is no conflict of interest.

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