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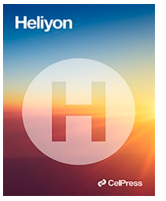

Research article

Waist-to-height ratio is a better predictor of hypertension in women during recovery from anesthesia compared to BMI, waist-to-hip ratio, and waist circumference

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ABSTRACT

This was an observational study of patients with benign breast tumors intended to investigate and compare the predictive value of body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) for hypertension in the recovery room. Logistic regression analysis was used to determine the association between these body fat anthropometric indices and hypertension. Receiver operating characteristic curve (ROC) analysis was performed to assess the comparative predictive ability. A total of 689 women were evaluated. Patients with BMI $\geq$28 (kg/m^2), WC $>$ 85 cm, WHR $\geq$0.82, and WHtR $\geq$0.5 had a significantly higher probability of increased systolic blood pressure (SBP) and diastolic blood pressure (DBP) than patients with less than threshold values (all $P < 0.05$). The areas under the ROC curve (AUC) of BMI, WC, and WHtR where all modestly significant (all AUC $\geq$0.65) and nearly identical at 0.6592, 0.65, and 0.6724, respectively. Conclusion: body fat anthropometric indices are useful predicting hypertension during recovery from general anesthesia in patients with benign breast tumors undergoing day surgery; WHtR outperformed the other indices and nearly identical.

1. Introduction

Obesity is a global public health problem. According to the World Health Organization, more than 1.9 billion people worldwide were found to be overweight, and more than 650 million were obese in 2016 [1]. According to the latest data in the Report on Nutrition and Chronic Diseases of Chinese Residents (2020), more than 50% of adults in China are overweight or obese, and the overweight and obesity rates among adult residents ($\geq$18 years old) are 34.3% and 16.4%, respectively [2]. Several studies have shown that obesity is an independent risk factor for hypertension, and different types of obesity also have some correlation with the blood pressure (BP) value; however, it is unknown whether this correlation holds true in patients recovering from general anesthesia [3–5]. Metabolism of anesthetic drugs is influenced by the fat distribution, and obese patients have a higher incidence of anesthesia-related complications compared to non-obese patients [6,7]. During recovery from general anesthesia, with the completion of the anesthetic drug metabolism, patients are prone to stress reactions such as elevated BP due to surgical trauma, postoperative pain, discomfort after endotracheal intubation, and other stimuli [8]. The increase in BP during recovery from general anesthesia can trigger postoperative

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bleeding, prolong stay in the post-anesthesia care unit (PACU), increase perioperative cost for patients, and adversely affect early postoperative rehabilitation of patients [9,10]. Benign breast tumor is a common breast disease, which is mainly treated by day surgery. The procedure is simple, minimally invasive, and generally does not exceed 24 h from admission to discharge [11]. Because of the short hospital stay, the perioperative management in the hospital is particularly important for the optimal recovery of the patient. Body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) are body fat anthropometric indices that can be used to define obesity and detect the risk for cardiovascular disease [12]. The study hypothesized that body fat anthropometric indices would predict the risk of hypertension in patients emerging from general anesthesia.

Therefore, the aim of this study was to evaluate the predictive effect of fat anthropometric indicators on hypertension during recovery from general anesthesia in patients with benign breast tumors, and to compare the predictive ability of BMI, WC, WHR, and WHTR in order to provide a reference for the management of BP during recovery from general anesthesia in patients with benign breast tumors undergoing day surgery.

2. Methods

2.1. Study design and population

This was a cross-sectional study. Patients with benign breast tumors who underwent day surgery at the Affiliated Hospital of Jining Medical University between February 2021 and August 2021 were included in the study. All patients in this study were anesthetized in the same way, with combined intravenous and inhalation anesthesia. Exclusion criteria were as follows: 1) age <18 years; 2) diagnosed with hypertension before surgery; 3) mental illness or unable to cooperate with the body measurements and questionnaires; 4) frozen pathological tissue was confirmed as malignant tumor during surgery by immunohistochemical examination; 5) refusal to participate in this study.

The Affiliated Hospital of Jining Medical University is located in Shandong Province, China, and undertakes the health care tasks of more than 20 million people in southwest Shandong Province, with an average annual number of 4 million outpatients. Shandong Province is the second largest population province in China, and sodium intake in Shandong Province is very high, with dietary salt intake reaching 12.5 g/day among residents in 2011 [13]. The Affiliated Hospital of Jining Medical University has 82 open clinical departments, 15 intensive care units and 4100 beds, which is a provincial regional medical center integrating teaching, scientific research and medical treatment. Written informed consent for the use of their clinical data for scientific research was obtained from all participants. This study was in full compliance with the Declaration of Helsinki and reviewed and approved by the Ethics Committee of the Affiliated Hospital of Jining Medical University (Approval Number: 2021C072, Application Date: January 01, 2021, Approval Date: January 23, 2021).

2.2. Data collection and definition

Before surgery, a general data questionnaire was used to investigate the general demographic and clinical characteristics (such as age, marriage, smoking, and drinking, hyperlipidemia, diabetes) of the study population.

In this study, current smoking and/or smoking cessation for less than 3 months was considered smoking; current drinking and/or drinking cessation for less than 3 months was considered drinking. Judgments of hyperlipidemia and/or diabetes were derived from self-report of physician diagnosis.

While waiting for the surgery, the patient wore a patient uniform and stood barefoot on an electronic scale to measure weight; a wall-mounted stadiometer was used to measure height; WC was measured at the smallest circumference between the iliac crest and thorax with an anthropometric tape, and hip circumference was measured at the largest width on the greater trochanter. These fat anthropometric indicators were retained to two decimal place.

During surgery, the nurse anesthesiologist in the operation room recorded the airway management method, operation duration, intraoperative blood loss, and infusion volume, and whether the urinary catheter/drainage tube/drainage strip was indwelled.

After surgery, the time to remove the laryngeal mask/endotracheal tube (recovery time = time to remove the laryngeal mask/endotracheal tube – time to complete surgery), blood pressure 5 min after removal of the laryngeal mask/endotracheal tube, and length of PACU stay were recorded by the nurse anesthesiologist in the PACU.

Blood pressure 5 min after the patient 's laryngeal mask airway/endotracheal tube was removed was obtained by an electrocardiogram monitor. When patients were admitted to PACU, nurse anesthesiologists in PACU selected the appropriate blood pressure cuff for the patient (the width of cuff balloon was 40% of arm circumference, and the length of cuff balloon was 80% of arm circumference), and blood pressure data were obtained every 3–5 min by an electrocardiogram monitor. Systolic blood pressure (SBP) $\geq$ 140 mmHg and/or diastolic blood pressure (DBP) $\geq$ 90 mmHg was judged as hypertension.

2.3. Different obesity indices and definitions

1) BMI = weight (kg)/height (m) ^{2}, BMI <24.0 kg/m^2 is normal weight, BMI = 24–27.9 kg/m^2 is overweight, BMI $\geq$28 kg/m^2 is obese [14,15]; 2) WC, WC < 85 cm is normal, WC $\geq$ 85 cm is abdominal obesity [16]; 3) WHR = waist circumference (cm)/hip circumference (cm), WHR <0.82 is normal, WHR $\geq$0.82 is increased WHR [17]; 4) WHtR = waist circumference (cm)/height (cm), WHtR <0.5 is normal, and WHtR $\geq$0.5 is increased WHtR [18].

2.4. Statistical analysis

Stata version 14.0 (StataCorp, College Station, TX, USA) was used for the data analysis. Enumeration data were expressed as frequency (n) and percentage (%); normally distributed measurement data were expressed as mean (X) and standard deviation (S), and non-normally distributed measurement data were expressed as median (M) and interquartile range (IQR). Chi-square test was used to compare the distribution of the number of patients with high SBP and high DBP under different fat anthropometric indicators. Multivariate logistic regression analysis was used to identify the anthropometric indices influencing the BP during recovery from general anesthesia, Receiver operating characteristic curve (ROC) was drawn to analyze the predictive value of the different fat anthropometric indicators for hypertension during recovery from general anesthesia. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Demographic and clinical characteristics

A total of 689 patients (mean age 39.2 years ±12.9 years) who underwent benign breast tumor resection were included in this prospective study (Fig. 1). All patients were women, most of them were married (88.7%), only a few had a history of smoking or drinking (<2%), and 184 (26.7%) developed hypertension during recovery from general anesthesia. Table 1 showed the patient demographics and clinical characteristics.

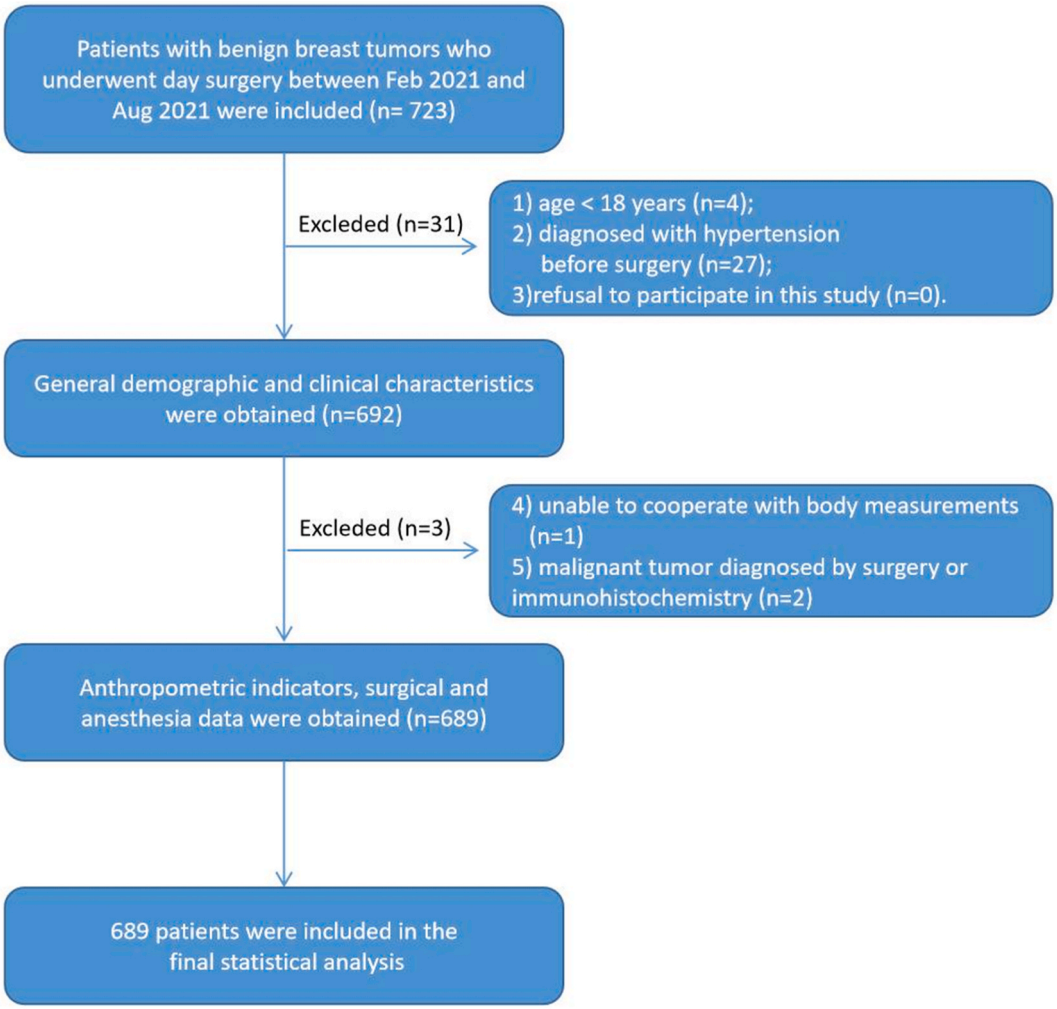

Fig. 1. Study flow diagram.

Table 1
Demographic and clinical characteristics of the patient population (n = 689).

Variables	Classification	n(%)/X(S)/M (IQR)
Demographic and Disease		
Age (year), (M (IQR))		38.0 (31.0–48.0)
Marriage, n(%)	unmarried	70 (10.2%)
	Married	611 (88.7%)
	Divorced/widowed	8 (1.2%)
Smoking (n, %)	Yes	4 (0.6%)
	No	685 (99.4%)
Drinking (n, %)	Yes	10 (1.5%)
	No	679 (98.5%)
Hyperlipidemia, n(%)	Yes	49 (7.1%)
	No	640 (92.9%)
Diabetes, n(%)	Yes	17 (2.5%)
	No	672 (97.5%)
Anthropometric indicators		
Height(cm), M (IQR)		160.0 (158.0–164.0)
Weight(Kg), M(IQR)		61.0 (55.0–67.0)
Waist circumference(cm), M (IQR)		80.0 (74.0–87.0)
Hip circumference(cm), M (IQR)		92.1 (86.0–98.0)
WC(cm), n(%)	<85	460 (66.8%)
	≥85	229 (33.2%)
WHR, n(%)	<0.82	113 (16.4%)
	≥0.82	576 (83.6%)
BMI(kg/m^2), n(%)	<28	606 (88.0%)
	≥28	83 (12.0%)
WHtR, n(%)	<0.5	331 (48.0%)
	≥0.5	358 (52.0%)
Surgical and Anesthesia		
Surgery duration(min), M(IQR)		30.0 (20.0–45.0)
Airway management	tracheal intubation	8 (1.2%)
	laryngeal mask	681 (98.8%)
Indwelling catheter, n(%)	Yes	16 (2.3%)
	No	673 (97.7%)
Indwelling drainage tube, n(%)	Yes	82 (11.9%)
	No	607 (88.1%)
Recovery time(min), M (IQR)		11.0 (6.0–15.0)
PACU duration(min), M(IQR)		35.0 (25.0–40.0)
Intraoperative blood loss(ml), M(IQR)		5.0 (5.0–10.0)
Intraoperative infusion volume(ml), M(IQR)		400.0 (400.0–600.0)
Preoperative systolic blood pressure(mmHg),X(S)		121.8(13.3)
Preoperative diastolic blood pressure(mmHg),X(S)		79.4(19.5)
Postoperative systolic blood pressure(mmHg), X(S)		127.2(17.0)
Postoperative diastolic blood pressure(mmHg),X(S)		80.3(10.7)

Note: M, Median; IQR, Interquartile range; PACU, post-anesthesia care unit; WC, Waist circumference; WHR, Waist-to-Hip Ratio; BMI, Body Mass Index; WHtR, Waist-to-height Ratio.

3.2. Distribution of the number of patients with high SBP and high DBP under different fat anthropometric indicators

The results showed that patients with BMI ≥28 (kg/m^2), WC > 85 cm, WHR ≥0.82, and WHtR ≥0.5 had a significantly higher probability of developing high SBP and DBP than patients with normal fat anthropometric indicators, and the differences were

Table 2
Distribution of the number of patients with high SBP and high DBP under different obesity indices (n = 689).

Obesity indicator	Categary	SBP(mmHg), n(%)			DBP(mmHg), n(%)		
		<140	≥140	P	<90	≥90	P
BMI(kg/m^2)	<28	482 (79.54%)	124 (20.46%)	0.006	520 (85.81%)	86 (14.19%)	0.001
	≥28	55 (66.27%)	28 (33.73%)		59 (71.08%)	24 (28.92%)	
WC(cm)	<85	383 (83.26%)	77 (16.74%)	<0.001	406 (88.26%)	54 (11.74%)	<0.001
	≥85	154 (67.25%)	75 (32.75%)		173 (75.55%)	56 (24.45%)	
WHR	<0.82	102 (90.27%)	11 (9.73%)	0.001	103 (91.15%)	10 (8.85%)	0.024
	≥0.82	435 (75.52%)	141 (24.48%)		476 (82.64%)	100 (17.36%)	
WHtR	<0.5	293 (88.52%)	38 (11.48%)	<0.001	299 (90.33%)	32 (9.67%)	<0.001
	≥0.5	244 (68.16%)	114 (31.84%)		280 (78.21%)	78 (21.79%)	

Note: BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure.

statistically significant (all $P < 0.05$), as shown in Table 2.

3.3. Logistic regression analysis of fat anthropometric indicators, and the risk of high SBP and DBP

Binary logistic regression was used to construct two models to analyze the relationship between BMI, WC, WHR, WHtR, and high SBP/DBP using high SBP/DBP as the dependent variable ("yes" = 1,"no" = 0) and BMI, WC, WHR, WHtR as the independent variables. After adjusting for general demographic characteristics and disease history, the results of Model 1 showed that increased WHR ($P = 0.006$) and WHtR ($P = 0.001$) were risk factors for high SBP; obesity ($P = 0.019$), abdominal obesity ($P = 0.004$), and increased WHtR ($P = 0.003$) were risk factors for high DBP. After further adjustment for surgery-related variables, the results of Model 2 showed that increased WHR ($P = 0.014$) and WHtR ($P = 0.005$) were independent risk factors for high SBP; abdominal obesity ($P = 0.009$) and increased WHtR ($P = 0.008$) were independent risk factors for high DBP, as shown in Table 3 and Fig. 2.

3.4. Predictive ability of fat anthropometric indicators for the risk of hypertension

ROC curves were used to analyze the predictive ability of the obesity indices for the risk of hypertension during emergence from general anesthesia. The results showed that except for WHR, the area under the ROC curve (AUC) values of BMI, WC, and WHtR for predicting hypertension during emergence from general anesthesia were ≥0.65, and WHtR had the best predictive ability (AUC = 0.67), as detailed in Table 4 and Fig. 3.

4. Discussion

According to the results of this study, WHtR and WHR were significantly correlated with high SBP, and WHtR and WC were significantly correlated with high DBP. BMI, WC, and WHtR had certain diagnostic value for hypertension during recovery from general anesthesia, with WHtR showing the highest predictive value among them. Thus, in accordance with previous studies, the body fat anthropometric measurements demonstrated to be highly correlated with hypertension during the anesthesia recovery [19]. The results of the present study add to the existing research data regarding the correlation between fat anthropometric indicators and BP values during recovery from general anesthesia, which is important in guiding the management of hypertension during recovery from general anesthesia in clinical practice.

Hypertension during recovery from general anesthesia is one of the common perioperative complications in the PACU, and its incidence ranges from 21.1% to 56.5% [20], which is similar to the results of the present study (26.7%). Hypertension during recovery from general anesthesia is associated with an increased incidence of postoperative admission to the ICU and mortality [21], and is an independent risk factor for prolonged hospital stay [8]. It has been shown that patients who develop severe hypertension during recovery from general anesthesia stay in the PACU for 1 additional hour compared to normotensive patients [22]. Therefore, the management of hypertension during emergence from general anesthesia is important to ensure the safety of patients and improve the quality of perioperative care of patients.

Obesity is well-known to be associated with hypertension [23–25]. Patients with BMI ≥28 (kg/m2), WC > 85 cm, WHR ≥0.82, and WHtR ≥0.5 had a significantly higher risk of increased BP. After adjusting for general data such as age, smoking, drinking, and surgery-related variables, we found that the body fat indices correlated with the BP during recovery from general anesthesia but WHtR was superior to the others (slightly more than WHR), in accordance with the correlation of these obesity indices with BP found in studies outside the anesthesia clinical setting [26–28]. Obesity impacts the pharmacokinetics and pharmacodynamics of anesthetic drugs [29], and since different anthropometric measures represent different patterns of fat deposition, increased fat mass increases the volume of distribution of lipophilic drugs and increases susceptibility to drug sensitivity [30]. This may be the potential mechanism by which different anthropometric measures may have different predictive effects on the risk of hypertension during recovery from general anesthesia.

Anthropometric parameters have been reported to have a good predictive ability for detecting hypertension, and our findings revealed that this conclusion is equally applicable to patients during recovery from general anesthesia. Our study showed that the AUC

Table 3
Logistic regression analysis of obesity indices and the risk of high SBP and high DBP (n = 689).

Obesity indicator	SBP (mmHg)		DBP (mmHg)	
	Model 1 OR (95%CI)	Model 2 OR (95%CI)	Model 1 OR (95%CI)	Model 2 OR (95%CI)
BMI(kg/m^2)	1.4 (0.8, 2.4) 0.306	1.2 (0.6, 2.2) 0.660	2.0 (1.1, 3.4) 0.019	1.8 (1.0, 3.3) 0.054
WC(cm)	1.5 (1.0, 2.3) 0.051	1.4 (0.9, 2.1) 0.172	1.9 (1.2, 3.0) 0.004	1.8 (1.2, 2.9) 0.009
WHR	2.8 (1.4, 5.9) 0.006	2.6 (1.2, 5.4) 0.014	1.9 (0.9, 3.8) 0.073	1.8 (0.9, 3.7) 0.104
WHtR	2.2 (1.4, 3.4) 0.001	2.0 (1.2, 3.1) 0.005	2.1 (1.3, 3.3) 0.003	1.9 (1.2, 3.2) 0.008

Note: BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; OR, Odds Ratio; CI, confidence interval.
Variables adjusted in Model 1: Age; smoking; drinking; diabetes; hyperlipidemia.
Variables adjusted in Model 2: Age; smoking; drinking; diabetes; hyperlipidemia; airway management; indwelling urinary catheter; indwelling drainage tube/strip; operation duration; intraoperative blood loss; intraoperative infusion volume.

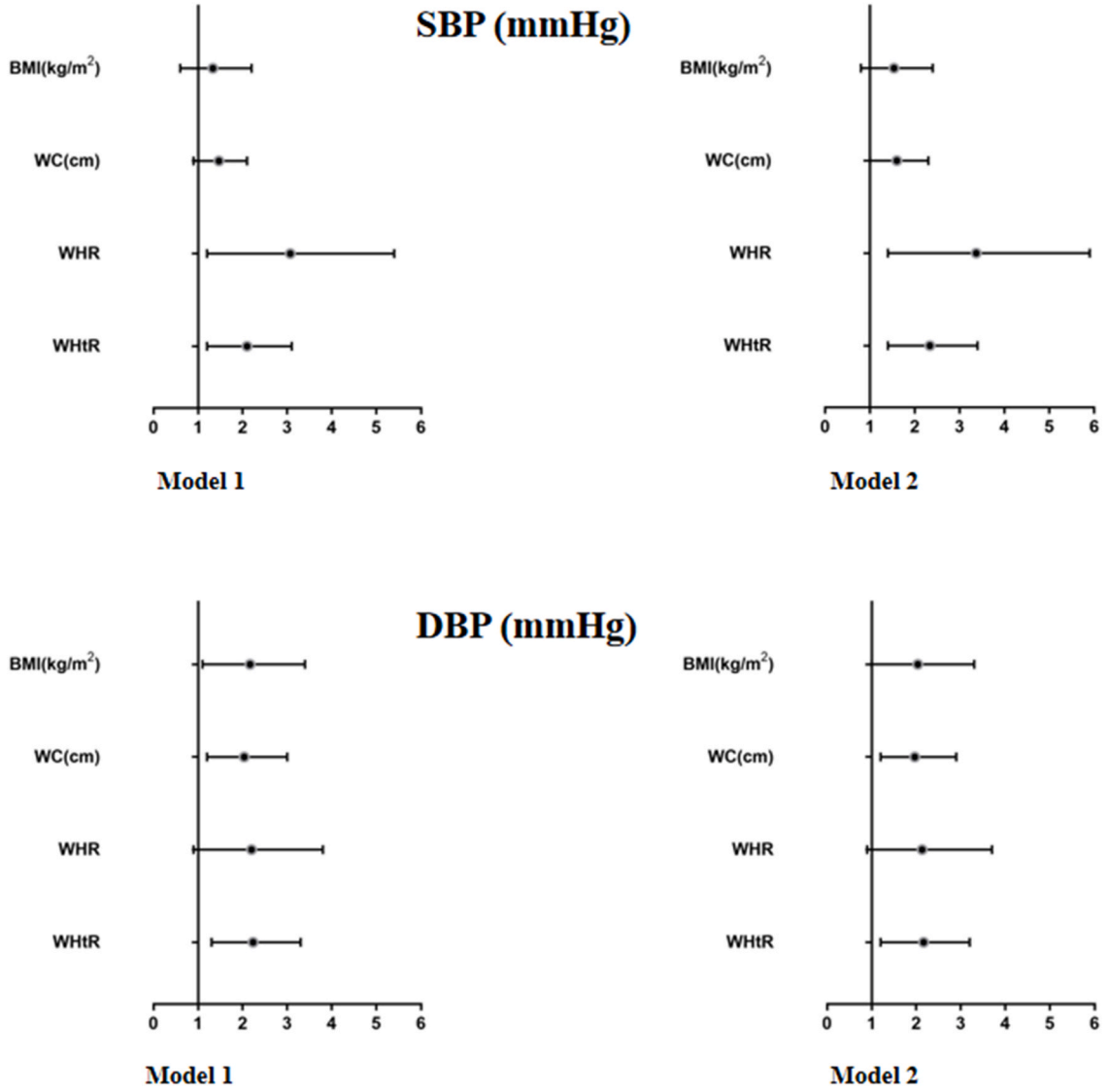

Fig. 2. Forest plot for OR risks of high SBP and high DBP according to obesity indices.

Table 4
Comparison of AUC of BMI, WC, WHR and WHtR for predicting the risk of hypertension.

Obesity Indicator	Obs	Area	Std. Err.	[95% Conf. Interval]		P-value
WC	689	0.6500	0.0234	0.6041	0.6959	0.0001
BMI	689	0.6592	0.0229	0.6143	0.7041	
WHR	689	0.5695	0.0234	0.5467	0.6383	
WHtR	689	0.6724	0.0227	0.6276	0.7165	

Note: BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; AUC, the area under the curve.

values of BMI, WC, and WHtR for predicting hypertension during recovery from general anesthesia were $\geq$0.65. This result are not unexpected given the high correlations between the individual indices. Shrestha et al. [18] investigated the current status of obesity and hypertension in 2256 outpatients, and found that WHtR and WC had a good predictive ability for hypertension in outpatients with an AUC $\geq$0.6, which is in accordance with the results of our study. However, Rajan et al. [18] did not investigate the predictive effect of WHR, and the findings were only applicable to hypertension screening in outpatients.

WHtR appears to have a better power in terms of its ability to predict hypertension [,31,32]. In our study, WHtR outperformed the other indices in predicting the risk of hypertension during recovery from general anesthesia (AUC = 0.67). This was similar to the

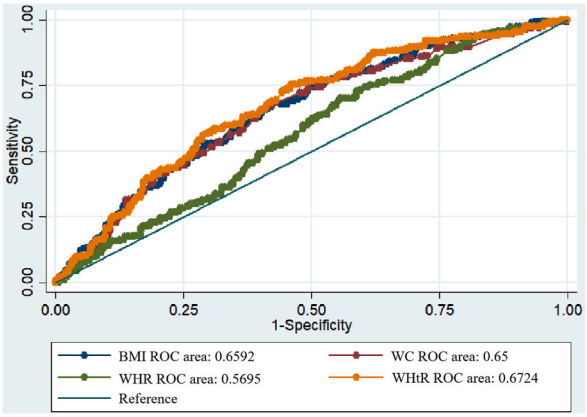

Fig. 3. ROC curves of fat anthropometric indicators to predict the risk of hypertension.

findings of Shi Luqian et al., who investigated 1906 residents in the community and found that WC and WHtR were more reflective of the risk of hypertension compared to BMI [33]. Deng et al. performed a meta-analysis of 309,585 subjects in 38 studies and came to the same conclusion [34]. They showed that WHtR was a good indicator for discriminating individuals at increased risk of hypertension, and in some cases, it was better than BMI, WC, and WHR [34]. Central obesity is strongly associated with pathological processes, and adipose tissue distributed in the central region of the body is more prone to inflammatory mediators, which may place patients at greater risk of obesity-related metabolic diseases as well as perioperative complications [35–37]. The above results suggest that central obesity indicators (such as WHtR) may be more clinically meaningful compared to the commonly used clinical obesity measures such as BMI. In particular, patients with normal BMI and increased WHtR should arouse the attention of researchers.

5. Strengths and limitations

One of the innovations of this study was to investigate the predictive value of anthropometric measures for hypertension during recovery from general anesthesia. To the best of our knowledge, this was the first study to apply anthropometric measurements to a population during recovery from general anesthesia, which is important for improving perioperative BP management and increasing the focus of researchers and administrators on perioperative patients. Second, the sample size of this study was sufficiently large, the research data were complete, and research results were stable, all of which will be useful as a reference for researchers. Third, the fat anthropometric indicators used were easy to obtain, non-invasive, and will not bring an economic burden, and the research method is worthy of promotion. However, the study also has some limitations. For example, the measurements of WC and hip circumference in that study were performed by only one observer, and these measurements may differ slightly even between trained health workers. In addition, there is no uniform standard for the cut-off values of fat anthropometric indicators, and the cut-off values of different countries and ethnic groups may vary, which may hinder the generalizability of the research results.

6. Conclusion

The present study found that fat anthropometric indicators were predictive of BP values during recovery from general anesthesia in patients with benign breast tumors undergoing day surgery. Increased WHR and WHtR were independent risk factors for high SBP during emergence from general anesthesia, while abdominal obesity and increased WHtR were independent risk factors for high DBP during emergence from general anesthesia. Compared to BMI, WC, and WHR, WHtR had the best predictive value for hypertension during emergence from general anesthesia.

Relevance for clinical practice

This study provides evidence that abdominal obesity is an important risk factor for the development of hypertension in patients during recovery from general anesthesia. BMI, WC, and WHtR showed similar predictive performance for hypertension, and may be used for risk assessment of hypertension in patients recovering from general anesthesia. This suggests that in clinical practice, we should pay attention to anthropometric indicators, especially those with BMI $\geq$28 (kg/m2), WC $>$ 85 cm, WHR $\geq$0.82, and WHtR $\geq$0.5, and take accurate preventive measures in a timely manner, which may be important to improve the management of perioperative blood pressure in patients.

Funding sources

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Ethics declarations

This study was reviewed and approved by the Ethics Committee of the Affiliated Hospital of Jining Medical University (Approval Number: 2021C072, Application Date: January 01, 2021, Approval Date: January 23, 2021).

All participants (or their proxies/legal guardians) provided informed consent to participate in the study.

Data availability statement

Research material relevant to the study is available. If necessary, it can be accessed by contacting the corresponding author.

CRediT authorship contribution statement

Qinqin Cao: Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Chengjuan Fan:** Writing – original draft, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Yufen Fei:** Writing – original draft, Supervision, Methodology, Investigation, Data curation. **Shouxin Zhang:** Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation. **Tong Shen:** Writing – original draft, Software, Methodology, Investigation, Data curation. **Haihong Meng:** Writing – review & editing, Resources, Project administration, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e28297.

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