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ORIGINAL ARTICLE

Prostate Cancer

Serum lipid profiles: novel biomarkers predicting advanced prostate cancer in patients receiving radical prostatectomy

Gui-Ming Zhang[1,2*], Xiao-Jian Qin[1,2*], Hai-Liang Zhang[1], Wen-Jun Xiao[1], Yao Zhu[1], Cheng-Yuan Gu[1], Bo Dai[1], Guo-Hai Shi[1], Ding-Wei Ye[1]

This study aimed to evaluate the role of serum lipid profiles as novel biomarkers in predicting pathological characteristics of prostate cancer (PCa). We retrospectively analyzed 322 consecutive patients with clinically localized PCa receiving radical prostatectomy (RP) and extended pelvic lymphadenectomy. Unconditional logistic regression was used to estimate the prostatectomy Gleason score (pGS), pathological stage and lymph node involvement (LNI) in RP specimens. Preoperative prostate-specific antigen (PSA) levels, biopsy GS (bGS), and preoperative tumor, node, metastasis staging were used as basic variables to predict postoperative pathological characteristics. Preoperative serum lipid profiles were introduced as potential predictors. A receiver operating characteristic (ROC) curve was used to determine predictive efficacy. Significant differences in pathological characteristics were observed among patients with normal and abnormal total cholesterol (TC), triglyceride (TG), and low-density lipoprotein (LDL) levels, with the exception of pGS in the TG group. Multivariable regression analysis revealed that the odds ratio for high levels of TC for LNI compared with normal TC levels was 6.386 (95% confidence interval [CI] 1.510–27.010), 3.270 (95% CI: 1.470–7.278) for high levels of TG for pT3–4 disease, and 2.670 (95% CI: 1.134–6.287) for high levels of LDL for pGS. The area under the ROC curve of the models with dyslipidemia was larger than that in models without dyslipidemia, in predicting pathological characteristics. Abnormal TC, TG, and LDL levels are significantly associated with postoperative pathological status in PCa patients. Together with preoperative PSA levels, bGS, and clinical stage, dyslipidemia is more accurate in predicting pathological characteristics.

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INTRODUCTION

In developed countries, prostate cancer (PCa) is the most common malignancy in men and the second leading cause of cancer-related mortality.[1] In China, the incidence of PCa has gradually increased over recent decades. According to the latest Chinese Cancer Registry Annual Report (2012), PCa has become the 6th most prevalent cancer and the 9th leading cause of cancer-related mortality in men, especially in urban areas.[2,3] Although the exact mechanisms that underlie PCa carcinogenesis are not well understood, growing evidence suggests that it is partly due to Western lifestyle factors, for example, a high-fat diet.[4,5]

Many studies have demonstrated that, as a predominant component of metabolic syndrome, dyslipidemia plays an important role in the carcinogenesis of various cancers. An increased risk of colon cancer has been observed in people with high triglyceride (TG) levels,[6] and hypercholesterolemia is considered as a risk factor for rectal cancer development.[7] A positive association between elevated low-density lipoprotein (LDL) levels and kidney cancer has been observed,[8] and low high-density lipoprotein (HDL) levels are associated with breast cancer and non-Hodgkin lymphoma.[9,10] To date, a large number of epidemiological studies have revealed an association between dyslipidemia and development of PCa.[11–14] In addition, patients with low total cholesterol (TC) levels are less likely to present with high-grade PCa (Gleason score [GS]≥8),[15] and inhibitors of 3-hydroxy-3-methylglutaryl coenzyme A reductase, also called statins and used for dyslipidemia treatment, reduce the risk of advanced PCa.[16,17] However, only a few studies have targeted the relationship between abnormal serum lipid levels and postoperative pathological status of PCa.

Together with preoperative prostate-specific antigen (PSA) levels, GS and pathological stage are critical risk factors determining the subsequent interventions after radical prostatectomy (RP); the most effective treatment for PCa patients with organ-confined disease (OCD). However, preoperative imaging currently has limitations with an accurate diagnosis of OCD and micrometastasis to pelvic lymph nodes. Given the intimate relationship between dyslipidemia and PCa, we hypothesized that abnormal levels of serum lipid profiles might be associated with postoperative pathological status

[1]Department of Urology, Fudan University Shanghai Cancer Center, Shanghai, China; [2]Department of Oncology, Shanghai Medical College, Fudan University, Shanghai, China.
*These authors contributed equally to this work.
Correspondence: Dr. DW Ye (dwyeli@163.com)
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and stage. The present investigation was designed to evaluate serum lipid profiles as novel biomarkers to predict pathological characteristics in PCa patients receiving RP.

PATIENTS AND METHODS

Study subjects

This was a retrospective analysis of 322 consecutive patients with clinically localized PCa who underwent RP and extended pelvic lymphadenectomy in Fudan University, Shanghai Cancer Center (FUSCC) from August 2012 to June 2013. None of the patients enrolled received neoadjuvant therapy. Data on age, history of hypertension or diabetes mellitus, family history of PCa, body mass index (BMI), smoking status, lipid profiles, statin usage, preoperative PSA levels, biopsy GS (bGS), histopathology, and stage at diagnosis (tumor, node, metastasis [TNM] classification) were obtained from electronic records and medical charts. Enzymatic methods were used to detect fasting serum lipid profiles by a Hitachi 7600 automatic clinical chemistry analyzer (Boehringer Mannheim, Mannheim, Germany) with reagent kits supplied by the manufacturer. Protocols were approved by the Institutional Research Review Boards of FUSCC, and written informed consent was obtained from all subjects.

Body mass index was defined as weight/height^2 (kg m^{-2}), and stratified according to guidelines for prevention and control of overweight and obesity in Chinese adults (<24: normal; ≥ 24: overweight).[18] Serum lipid profiles were stratified in accordance with the Chinese Guidelines on Adult Dyslipidemias (2007 version);[19] preoperative PSA levels, bGS, and clinical stage were divided into high-, medium-, and low-risk groups, respectively.[20]

To establish a relationship between preoperative predictive factors and postoperative pathological characteristics, preoperative PSA levels, bGS, and clinical stage were used as basic variables, and preoperative lipid profiles were introduced as potential predictive variables. Age, BMI, hypertension, diabetes, family history of PCa, smoking status, and statin usage were included in the analyses as potential confounders.

Statistical analysis

Differences in categorical variables were compared using χ^2 tests. Unconditional multiple logistic regression was used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of the probability of lymph node involvement (LNI), pT3–4 disease, and prostatectomy GS (pGS) in RP specimens. A receiver operating characteristic (ROC) curve was used to determine the efficacy of the predictive variables. The values of P were two sided, and $P < 0.05$ was considered statistically significant. SPSS version 20.0 (IBM Corporation, Somers, NY, USA) was used for statistical analyses.

RESULTS

The study included 322 cases of newly diagnosed PCa (age range: 47–79 years, median age: 68 years), whose preoperative PSA levels were in the range of 3.7–143.0 ng ml^{-1} (median: 14.34 ng ml^{-1}). There were 172, 90, and 60 patients with ≤cT2a, cT2b, and cT2c disease, respectively, according to the American Joint Committee on Cancer TNM staging system (2002). Distribution of PCa cases according to demographic and clinical characteristics is indicated in **Table 1**.

No significant differences in age, hypertension, and statin usage were observed between patients with normal and abnormal levels in TC, TG, LDL and HDL groups. Differences in preoperative PSA levels, bGS, clinical stage, smoking status, BMI, diabetes, pGS, pathological stage, and LNI varied in different groups. As far as postoperative pathological characteristics were concerned, notable differences existed among the TC, TG, and LDL groups, with the exception of pGS in the TG group. Interestingly, there were no differences observed between patients with normal and abnormal HDL levels (**Table 1**).

We investigated the association of postoperative pathological characteristics with preoperative PSA levels, bGS, a clinical stage, and TC, TG, and LDL levels, using univariate and multivariable logistic regression models, respectively. As shown in **Table 2**, after adjusting for potential confounders, high levels of TC were associated with increased risk of LNI (OR: 6.386, 95% CI: 1.510–27.010), and elevated TG levels were associated with a more than two-fold increased risk of pT3–4 disease (OR: 3.270, 95% CI: 1.470–7.278). In addition, high levels of LDL were an independent predictor of pGS ≥8 (OR: 2.670, 95% CI: 1.134–6.287). Further, we examined the OR (95% CI) of postoperative pathological characteristics when a patient harbored one, two or all three of the lipid-related risk factors. With the increase of the number of abnormal lipid components, a higher probability of pT3–4 disease and LNI was observed, yet no significant association was found with respect to pGS, whether in univariate or multivariable logistic regression models (**Table 2**).

We used ROC curves to detect the efficacy of predictive variables for postoperative pathological characteristics of PCa. The models were constructed using preoperative PSA levels, bGS, and clinical stage, with or without lipid profiles. As shown in **Figure 1**, area under the ROC curve of the models with dyslipidemia was larger than that without dyslipidemia, with regard to all the pathological status, including pGS, pT3–4 disease, and LNI.

DISCUSSION

There was a significant association between dyslipidemia and postoperative pathological characteristics, including pGS, pT3–4 disease, and LNI, and the association persisted after adjusting for multiple risk factors for PCa and other lipid parameters. Furthermore, ROC curve analysis suggested that abnormal lipid levels might be efficient predictors of pathological status of PCa.

In recent years, much attention has been focused on the association of lipid profiles with PCa, with conflicting conclusions. As far as TC is concerned, although controversy remains, many researchers have found a positive association between TC levels and total PCa incidence.[21–23] Some prospective studies did not show increased total PCa risks in populations with high TC levels, whereas increased risk of high-grade or advanced PCa was seen.[24–26] Apart from this epidemiological evidence, statins are also protective against the development of advanced PCa.[16,17] Our study adds to the literature supporting the relationship between dyslipidemia and PCa development. Mondul *et al*.[26] conducted a large cohort study and found that men with normal TC levels were less likely to develop high-grade PCa. Similarly, another study conducted by Platz *et al*.[25] reported that men with < 200 mg dl^{-1} TC had a lower risk of PCa with GS > 7. Our study focused on the relationship between dyslipidemia and postoperative pathological characteristics of PCa. Although the association of different serum lipid components with pathological status and stage varied, we did observe that dyslipidemia contributed to PCa progression. Several vital prognostic factors, such as pGS, pT3–4 disease, and LNI, were closely related to elevated LDL, TG, and TC levels, respectively. Abnormal HDL levels seemed not to be associated with PCa prognosis in our study, although a close relationship was reported between low HDL levels and PCa risk.[23] However, a large-scale external validation of these results is warranted.

At present, the exact molecular mechanisms associated with the role of dyslipidemia in PCa carcinogenesis remain unclear, although several explanations have been proposed. Abnormal regulation of

Table 1: Demographic and clinical characteristics stratified by serum lipid profiles in PCa patients receiving RP

Variables	*TC*			*TG*			*LDL*			*HDL*		
	n (%)		*P*	*n (%)*		*P*	*n (%)*		*P*	*n (%)*		*P*
	Normal (<200 mg dl^{-1})	*Abnormal (≥200 mg dl^{-1})*		*Normal (<150 mg dl^{-1})*	*Abnormal (≥150 mg dl^{-1})*		*Normal (<130 mg dl^{-1})*	*Abnormal (≥130 mg dl^{-1})*		*Normal (≥40 mg dl^{-1})*	*Abnormal (<40 mg dl^{-1})*	
Age (year)												
<68	102 (47.2)	50 (47.2)	0.993	106 (44.2)	46 (56.1)	0.062	96 (46.6)	56 (48.3)	0.773	136 (47.2)	16 (47.1)	0.986
≥68	114 (52.8)	56 (52.8)		134 (55.8)	36 (43.9)		110 (53.4)	60 (51.7)		152 (52.3)	18 (52.9)	
Preoperative PSA												
<10	76 (35.2)	18 (17.0)	0.003	74 (30.8)	20 (24.4)	0.374	68 (33.0)	26 (22.4)	0.133	88 (30.6)	6 (17.6)	0.268
10≤ PSA <20	74 (34.3)	48 (45.3)		86 (35.9)	36 (43.9)		74 (35.9)	48 (41.4)		108 (37.5)	14 (41.2)	
≥20	66 (30.5)	40 (37.7)		80 (33.3)	26 (31.7)		64 (31.1)	42 (36.2)		92 (31.9)	14 (41.2)	
bGS												
Low (≤6)	78 (36.1)	22 (20.8)	0.003	74 (30.8)	26 (31.7)	0.842	76 (36.9)	24 (20.7)	0.010	92 (31.9)	8 (23.5)	0.599
Middle (=7)	90 (41.7)	44 (41.5)		102 (42.5)	32 (39.0)		78 (37.9)	56 (48.3)		118 (41.0)	16 (47.1)	
High (≥8)	48 (22.2)	40 (37.7)		64 (26.7)	24 (29.3)		52 (25.2)	36 (31.0)		78 (27.1)	10 (29.4)	
Clinical stage												
cT1c/2a	112 (51.9)	60 (56.6)	0.116	128 (53.3)	44 (53.7)	0.085	102 (49.5)	70 (60.3)	0.006	155 (53.8)	17 (50.0)	0.568
cT2b	57 (26.4)	33 (31.1)		73 (30.4)	17 (20.7)		55 (26.7)	35 (30.2		78 (27.1)	12 (35.3)	
cT2c	47 (21.7)	13 (12.3)		39 (16.3)	21 (25.6)		49 (23.8)	11 (9.5)		55 (19.1)	5 (14.7)	
Smoking status												
Ever	60 (27.8)	46 (43.4)	0.005	82 (34.2)	24 (29.3)	0.415	66 (32.0)	40 (34.5)	0.654	90 (31.3)	16 (47.1)	0.064
Never	156 (72.2)	60 (56.6)		158 (65.8)	58 (70.7)		140 (68.0)	76 (65.5)		198 (68.7)	18 (52.9)	
BMI												
Normal (<24)	98 (45.4)	48 (45.3)	0.988	124 (51.7)	22 (26.8)	<0.001	98 (47.6)	48 (41.4)	0.284	140 (48.6)	6 (17.6)	0.001
Overweight (≥24)	118 (54.6)	58 (54.7)		116 (48.3)	60 (73.2)		108 (52.4)	68 (58.6)		148 (51.4)	28 (82.4)	
Hypertension												
Yes	36 (16.7)	16 (15.1)	0.719	40 (16.7)	12 (14.6)	0.666	34 (16.5)	18 (15.5)	0.817	48 (16.7)	4 (11.8)	0.463
No	180 (83.3)	90 (84.9)		200 (83.3)	70 (85.4)		172 (83.5)	98 (84.5)		240 (83.3)	30 (88.2)	
Diabetes												
Yes	26 (12.0)	16 (15.1)	0.444	24 (10.0)	18 (22.0)	0.006	26 (12.6)	16 (13.8)	0.764	28 (9.7)	14 (41.2)	<0.001
No	190 (88.0)	90 (84.9)		216 (90.0)	64 (78.0)		180 (87.4)	100 (86.2)		260 (90.3)	20 (58.8)	
Statin usage												
Yes	12 (5.6)	2 (1.9)	0.129	10 (4.2)	4 (4.9)	0.785	10 (4.9)	4 (3.4)	0.553	12 (4.2)	2 (5.9)	0.643
No	204 (94.4)	104 (98.1)		230 (95.8)	78 (95.1)		196 (95.1)	112 (96.6)		276 (95.8)	32 (94.1)	
prostatectomy GS												
Nonhigh risk (≤7)	166 (76.9)	70 (66.0)	0.039	178 (74.2)	58 (70.7)	0.544	162 (78.7)	74 (63.8)	0.004	212 (73.7)	24 (70.6)	0.706
High risk (≥8)	50 (23.1)	36 (34.0)		62 (25.8)	24 (29.3)		44 (21.3)	42 (36.2)		76 (26.3)	10 (29.4)	
Pathological stage												
pT2	158 (73.1)	44 (41.5)	<0.001	164 (68.3)	38 (46.3)	<0.001	148 (71.8)	54 (46.6)	<0.001	182 (63.2)	20 (58.8)	0.618
pT3-4	58 (26.9)	62 (58.5)		76 (31.7)	44 (53.7)		58 (28.2)	62 (53.4)		106 (36.8)	14 (41.2)	
LNI	10 (4.6)	20 (18.9)	<0.001	17 (7.1)	13 (15.8)	0.018	12 (5.8)	18 (15.5)	0.004	28 (9.7)	4 (11.8)	0.604

PCa: prostate cancer; RP: radical prostatectomy; PSA: prostate-specific antigen; bGS: biopsy Gleason score; BMI: body mass index; GS: Gleason score; LNI: lymph node involvement; TC: total cholesterol; TG: triglyceride; LDL: low-density lipoprotein; HDL: high-density lipoprotein

cholesterol metabolism may result in elevated cholesterol levels in PCa cells. Meanwhile, aberrant lipid metabolism can influence signal transduction in PCa, for example, through promoting cancer cell growth and inhibiting apoptosis.[27] Androgen receptors located in PCa cells can recruit several transcription factors involved in lipid metabolism,[28] of which sterol regulatory element binding protein 2 is notably upregulated in PCa cell xenograft tumors.[29] In addition, several important signaling pathways involved in carcinogenesis, such as Akt and sonic hedgehog pathways, are the cholesterol sensitive.[30,31] Hence, abnormal serum lipid levels may promote these pro-carcinogenic process in PCa.

Given the important role of dyslipidemia in PCa development and progression, we hypothesized that lipid profiles might be potential biomarkers to predict advanced disease. The present study verified our speculation. Besides preoperative PSA, bGS, and clinical stage, we introduced preoperative TC, TG, and LDL levels into the predictive model, and higher efficiency was observed. Therefore, our results suggest that information about preoperative serum lipid profiles may improve the accuracy of pathological prediction and enable the choice of more appropriate medical intervention.

Furthermore, our results provided another clinical implication. It is well known that dyslipidemia functions as a critical risk factor in the development of coronary artery disease (CAD), which remains a leading cause of health impairment worldwide.[32] Intriguingly, some recent studies have found a significant association of CAD with increased PCa diagnosis, and speculated that CAD share etiology with

Table 2: Logistic regression analysis of the association between serum lipid profiles and pathological characteristics in PCa patients

Variables	*Prostatectomy GS*						*Pathological stage*						*Lymph node involvement*					
	≤7	*≥8*	*Crude OR (95% CI)*	*P*	*Adjusted* OR (95% CI)*	*P*	*pT2*	*pT3-4*	*Crude OR (95% CI)*	*P*	*Adjusted* OR (95% CI)*	*P*	*Yes*	*No*	*Crude OR (95% CI)*	*P*	*Adjusted* OR (95% CI)*	*P*
Preoperative PSA																		
<10	84	10	Reference	<0.001	Reference	0.026	90	4	Reference	<0.001	Reference	<0.001	3	91	Reference	0.001	Reference	0.001
10≤ PSA <20	86	36	3.516 (1.641-7.537)	0.001	2.583 (1.052-6.340)	0.038	68	54	17.868 (6.170-51.745)	<0.001	20.131 (5.790-69.985)	<0.001	7	115	1.846 (0.464-7.340)	0.384	1.507 (0.285-7.967)	0.629
≥20	66	40	5.091 (2.371-10.932)	<0.001	3.417 (1.401-8.333)	0.007	44	62	31.705 (10.837-92.751)	<0.001	34.941 (9.901-123.308)	<0.001	20	86	7.054 (2.024-24.592)	0.002	8.491 (1.815-39.717)	0.007
bGS																		
Low (≤6)	92	8	Reference	<0.001	Reference	<0.001	86	14	Reference	<0.001	Reference	<0.001	2	98	Reference	0.031	Reference	0.060
Middle (=7)	104	30	3.317 (1.448-7.599)	0.005	2.925 (1.202-7.115)	0.018	86	48	3.429 (1.761-6.674)	<0.001	3.537 (1.500-8.337)	0.004	17	117	7.120 (1.605-31.576)	0.010	9.421 (1.454-61.060)	0.019
High (≥8)	40	48	13.800 (5.985-31.821)	<0.001	13.004 (4.991-33.881)	<0.001	30	58	11.876 (5.801-24.313)	<0.001	8.947 (3.600-22.236)	<0.001	11	77	7.000 (1.507-32.519)	0.013	9.286 (1.257-68.597)	0.029
Clinical stage																		
cT1c/2a	132	40	Reference	0.146	Reference	0.615	116	56	Reference	0.090	Reference	0.205	16	156	Reference	0.345	Reference	0.266
cT2b	59	31	1.734 (0.990-3.037)	0.054	1.425 (0.704-2.885)	0.325	55	35	1.318 (0.776-2.240)	0.307	1.355 (0.632-2.905)	0.435	11	79	1.358 (0.602-3.064)	0.462	1.003 (0.346-2.907)	0.995
cT2c	45	15	1.100 (0.556-2.178)	0.784	1.168 (0.498-2.738)	0.722	31	29	1.938 (1.065-3.525)	0.030	2.143 (0.915-5.022)	0.079	3	57	0.513 (0.144-1.827)	0.303	0.294 (0.065-1.328)	0.112
TC																		
Normal (<200 mg dl^{-1})	166	50	Reference	0.040	Reference	0.228	158	58	Reference	<0.001	Reference	0.081	10	206	Reference	<0.001	Reference	0.012
Abnormal (≥200 mg dl^{-1})	70	36	1.707 (1.024-2.847)		0.572 (0.231-1.417)		44	62	3.839 (2.352-6.264)		2.106 (0.913-4.862)		20	86	4.791 (2.153-10.659)		6.386 (1.510-27.010)	
TG																		
Normal (<150 mg dl^{-1})	178	62	Reference	0.544	Reference	0.764	164	76	Reference	<0.001	Reference	0.004	17	223	Reference	0.021	Reference	0.315
Abnormal (≥150 mg dl^{-1})	58	24	1.188 (0.681-2.073)		0.892 (0.422-1.883)		38	44	2.499 (1.497-4.170)		3.270 (1.470-7.278)		13	69	2.471 (1.143-5.343)		1.767 (0.582-5.361)	
LDL																		
Normal (<130 mg dl^{-1})	162	44	Reference	0.004	Reference	0.025	148	58	Reference	<0.001	Reference	0.434	12	194	Reference	0.006	Reference	0.393
Abnormal (≥130 mg dl^{-1})	74	42	2.090 (1.262-3.460)		2.670 (1.134-6.287)		54	62	2.930 (1.823-4.709)		1.411 (0.596-3.338)		18	98	2.969 (1.375-6.412)		0.540 (0.131-2.220)	
Number of abnormal lipid components§																		
0	124	36	Reference	0.068	Reference	0.210	118	42	Reference	<0.001	Reference	<0.001	6	154	Reference	0.004	Reference	0.019
1	50	14	0.964 (0.479-1.941)	0.919	0.755 (0.337-1.691)	0.495	44	20	1.277 (0.677-2.410)	0.450	0.707 (0.309-1.614)	0.410	6	58	2.655 (0.823-8.565)	0.102	2.032 (0.532-7.767)	0.300
2	34	20	2.026 (1.042-3.941)	0.038	1.901 (0.856-4.220)	0.114	28	26	2.609 (1.376-4.945)	0.003	3.170 (1.316-7.633)	0.010	9	45	5.133 (1.734-15.193)	0.003	4.95 (1.293-18.604)	0.019
3	28	16	1.968 (0.960-4.034)	0.064	1.486 (0.644-3.428)	0.353	12	32	7.492 (3.535-15.879)	<0.001	13.372 (4.870-36.719)	<0.001	9	35	6.600 (2.205-19.753)	0.001	7.770 (1.997-30.236)	0.003

*Adjusted for age, BMI, hypertension, diabetes, smoking status, statin usage, preoperative PSA, bGS, clinical stage, TC, TG and LDL; §Adjusted for age, BMI, hypertension, diabetes, smoking status, statin usage, preoperative PSA, bGS, clinical stage. PCa: prostate cancer; PSA: prostate-specific antigen; bGS: biopsy Gleason score; GS: Gleason score; TC: total cholesterol; TG: triglyceride; LDL: low-density lipoprotein; OR: odds ratio; CI: confidence interval; BMI: body mass index

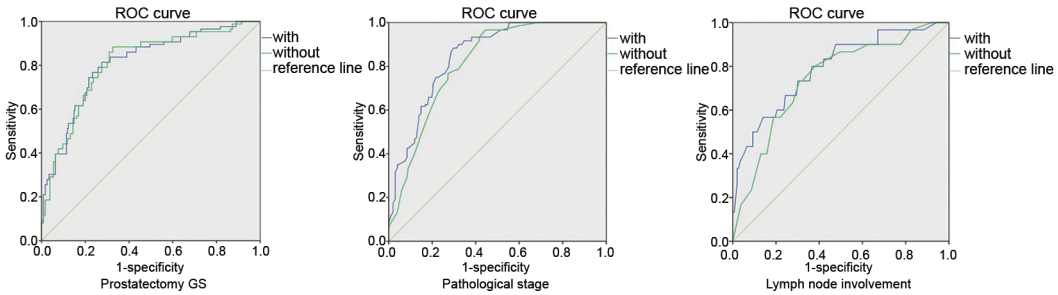

Figure 1: ROC curve of pathological characteristics and dyslipidemia: area under the ROC curve of the models with dyslipidemia was larger than that without dyslipidemia, with regard to pGS (0.810 *vs* 0.808), pT3–4 disease (0.848 *vs* 0.814), and LNI (0.791 *vs* 0.745). ROC: receiver operating characteristic; pGS: prostatectomy Gleason score; LNI: lymph node involvement.

PCa.[33,34] Now that dyslipidemia plays an important role in both CAD and PCa development, we believe that better control of dyslipidemia may obtain more benefits than we have expected.

Our study had certain limitations and constraints. First, it was conducted in a single medical center with a small sample, and the results were subject to inherent biases of a retrospective nature. Second, unlike the Partin table,[35] we stratified preoperative PSA levels, bGS, and clinical stage in a simple manner. It is uncertain whether more precise stratification might have influenced the predictive efficacy. Finally, although dyslipidemia was suggested as a prognostic factor, different serum lipid components had various relationships with pathological status. A consistent association was not observed between a certain lipid component and pathological characteristics. Clearly, additional prospective studies are necessary to validate our observations in a large population.

CONCLUSIONS

The present study found a significant association between elevated serum TC, TG, and LDL levels and pathological characteristics in PCa patients. Together with preoperative PSA levels, bGS, and clinical stage, dyslipidemia is a novel and useful predictive biomarker for advanced PCa patients. Dyslipidemia is common and preventable; therefore, large prospective, population-based studies are warranted.

AUTHOR CONTRIBUTIONS

GMZ and XJQ designed the study, collected, analyzed and interpreted the clinical data, and wrote the manuscript. HLZ, WJX, YZ and CYG collected part of the patients' clinical data. BD and GHS analyzed part of the data. DWY supervised the project and revised the manuscript. All authors vouch for the respective data and analysis, approved the final version and agreed to publish the manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interest.

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