

RESEARCH ARTICLE

Predictive value of pressure ulcer risk for obstructive coronary artery disease

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Funding information

Dr. Huang is currently receiving a grant from Key Research and Development Projects of Science & Technology Department of Sichuan Province (2019YFS0351).

Abstract

Aim: To investigate the relationship between pressure ulcers risk and severity of obstructive coronary artery disease (CAD) by invasive coronary angiography.

Design: Cross-sectional study.

Methods: A total of 193 consecutive patients with underlying pressure ulcers risk who underwent invasive coronary angiography were enrolled. Subjects were divided into three groups according to severity of coronary artery stenosis. Pressure ulcers risk score, fall risk score, self-care ability score and cardiovascular risk factors were compared among the three groups. Multivariate regression analysis and receiver operating curve analysis were performed to explore the diagnostic value of Braden score for left main or three-vessel disease.

Results: Patients with more severe CAD had higher pressure ulcers risk. The percentage of high-pressure ulcers risk was highest in left main or three-vessel disease group, compared with control group and single- or two-vessel disease group. After adjusting for age, body mass index, diabetes, chronic kidney disease and other confounding factors, Braden score was an independent predictor of left main or three-vessel disease. Moreover, higher Braden score had a moderate area under the curve for excluding more severe CAD. In conclusion, among patients planning for coronary angiography, pressure ulcers risk assessment is conducive to predict the severity of obstructive CAD.

KEYWORDS

coronary artery disease, predictive value, pressure ulcers

1 | INTRODUCTION

Accompanied by population ageing, urbanization and lifestyle changes, ischaemic heart disease has ranked as the leading cause of death worldwide (Finegold et al., 2013). For both sexes, the risk of incident coronary artery disease (CAD) increased markedly with age (Lowenstern et al., 2020). As people get older, their physical function is weakened, nutritional status is falling, and immune function

is declining; all of these changes contributed to the thin and dry skin, decreased subcutaneous tissue and dull sensation (Jaul, 2010; Levine, 2020). With local compression, the skin and subcutaneous tissue are susceptible to suffer from ischaemia and hypoxia, which lead to the occurrence of pressure ulcers (Boyko et al., 2018). Previous study showed that the incidence of pressure ulcers was associated with age. Patients over 40 years old were about 2 ~ 10 times more likely to develop pressure ulcers than those less than 40 years

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old; moreover, nearly seventy per cent of pressure ulcers occurred in older people over 70 years old (Perneger et al., 1998). International Clinical Practice 2019 on Prevention and treatment of pressure ulcers recommends that considering individuals with limited mobility/limited activity to be at risk of pressure injuries; besides, the guidelines suggest to consider the impact of older age, diabetes mellitus, oxygenation deficits, impaired nutritional status, general and mental health status, etc., on the risk of developing pressure injuries (EPUAP, NPIAP, & PPIA, 2019). All of the above factors are also identified as risk factors for CAD as demonstrated in the 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes (Knuuti et al., 2020). Skin health could act as a window to reflect cardiovascular health. It has been shown that skin ageing is associated with degenerative atrioventricular block and facial features are helpful in detecting CAD (Lin et al., 2020; Roshdy et al., 2018). In a multi-centre cross-sectional study, Lin et al. found that frontparietal baldness, crown top baldness, earlobe crease, preauricular crease, heavy pouch, deep crows-feet, deep forehead wrinkle, periorbital wrinkle, nasal folds, deep nasolabial sulcus, age spots, oral pale and other facial features were considered to be significantly associated with CAD using a computer deep learning algorithm. The accuracy of the facial features-based CAD detection algorithm was significantly higher than that of the traditional Diamond-Forrester model and the widely used CAD consortium clinical score (Lin et al., 2020). Since the formation of pressure ulcers is the result of the comprehensive action of local and systemic factors and patients with CAD are more susceptible to suffer from pressure ulcers, in this study, we attempt to investigate whether pressure ulcers risk score can predict the severity of obstructive CAD confirmed by coronary angiography and improve positive rate of coronary angiography.

2 | BACKGROUND

Invasive coronary angiography is the gold standard for the diagnosis of CAD. However, results from National Cardiovascular Data Registry of the US demonstrated that of the 398 978 patients with suspected CAD, only 37.6% (149,739 patients) were diagnosed with obstructive CAD after coronary angiography. In contrast, 39.2% of patients have <20% stenosis in all coronary vessels. The low diagnostic yield of coronary angiography suggests that better optimizing strategy for screening and risk stratification for patients with chest pain are required (Patel et al., 2010). In contemporary practice, the initial clinical assessment of patients with angina and /or suspected CAD uses age, sex and the nature of symptoms to establish pre-test probabilities of obstructive CAD (Knuuti et al., 2020). A man older than 70 years who has typical angina has a probability of 52% to suffer from obstructive CAD, while women aged 30–39 who has atypical angina have merely a possibility of as low as 1% to get obstructive CAD (Knuuti et al., 2020). Although this simple clinical approach is of value for distinguishing patients with CAD from those with symptoms of chest pain because of other causes to some extent, it can be perceived that even a patient meets all of three clinical

characteristics, only half of the chance the patient has obstructive CAD. Myocardium ischaemia can be reflected on electrocardiogram while its sensitivity is limited, especially for those with stable plaque. In order to improve the diagnostic yield of coronary angiography, physicians combine the information of cardiovascular risk factors, functional test, coronary computed tomography (CT), coronary calcium score, etc. to determine which patients should receive further coronary angiography (Foy et al., 2017; Hoffmann et al., 2017; Nicoll et al., 2016). However, among these methods, functional testing has potential risks of inducing malignant arrhythmias or acute coronary events, while CT examination carries the risk of radiation and contrast induced nephropathy or allergy. In the circumstances, more simplified way by which we can improve the accuracy of pre-test probability of patients with suspected CAD and the positive rates of invasive coronary angiography are required to rationalize the invasive procedures, especially for patients in stable conditions (the diagnosis of acute coronary syndrome had a special pathway that was distinct from stable CAD). Pressure ulcers risk assessment is a part of routine clinical care at admission, which is also a major goal of nursing safety. As pressure ulcers risk reflects the general health status of the body and cardiovascular disease can be presented as skin change, it seems that ulcers risk assessment may be helpful in stratifying patients' cardiovascular risk through clinical visits and quick evaluation, and improving decision-making efficiency. The aims of present study were to observe whether pressure ulcers risk assessment was conducive to identify patients with obstructive CAD from those with chest pain or other indicators of myocardial ischaemia; moreover, whether it was helpful to stratify patients with different severity of CAD.

3 | METHODS

3.1 | Study population

This was a cross-sectional study. Of the total of 697 patients who underwent coronary angiography in our department between January–February 2019, we excluded 451 patients without pressure ulcer risk evaluation due to perceived low risk and 53 patients for perioperative assessment, at last, 193 patients with underlying risk of pressure ulcers who received assessment at admission were consecutively enrolled. Other nursing evaluation including self-care ability and fall risk were also assessed when admitted. Baseline characteristics, medical history, laboratory variables and coronary angiography results were also collected to construct dataset. This study was performed in line with the principles of the Declaration of Helsinki. Informed consent was waived due to the retrospective design of the study and minimal risk to investigated subjects.

Hypertension was diagnosed when a person's systolic blood pressure (SBP) in the office or clinic is ≥ 140 mm Hg and/or their diastolic blood pressure (DBP) is ≥ 90 mm Hg following repeated examination (Unger et al., 2020) Type 2 diabetes was diagnosed based on fasting blood glucose ≥ 7.0 mmol/L, or 2 hr glucose tolerance test showing a

glucose level ≥ 11.1 mmol/L. Smoking was defined as someone who had smoked at least 1 cigarette per day, continued for more than 1 year and smoked at admission or quit smoking less than half a year. Barthel Index Scoring was used to assess self-care ability. The scoring ranks the patient's independence in ten areas, including feeding, bathing, grooming, dressing, bowel control, bladder control, toilet use, transfers (bed to chair and back), mobility on level surfaces and stairs. Each item was assigned a score from zero–15, according to the patients' independence. The total score was calculated and patients who had score ≥ 40 were assigned to the low-risk group, while those had score < 40 were defined as high-risk group (very or totally dependent) (Mahoney & Barthel, 1965). Fall risk was assessed using a revised version of Johns Hopkins Fall Risk Assessment Scale (Poe et al., 2018). The assessment included 10 items, including age, cognitive ability, mobility, excretion ability, fall/fall out of bed in the previous year of hospitalization, current use of special medications such as sedatives or analgesics, binocular vision impairment, low compliance or communication disorders, restlessness and other risk factors. An aggregate score < 4 indicated low-risk group, while score ≥ 4 suggested high-risk group.

3.2 | Classification of severity of CAD

According to the results of coronary angiography, the patients were divided into three groups. Control group: patients with non-obstructive coronary atherosclerosis, defined as angiography results showing absence of narrowing of coronary arteries, or left main stenosis $< 30\%$, or single-vessel (left anterior descending artery, left circumflex artery, or right coronary artery) stenosis besides left main trunk $< 50\%$; single- or two-vessel disease group: stenoses in one or two of the epicardial coronary arteries $\geq 50\%$; left main or three-vessel disease group: stenosis in the left main artery $\geq 30\%$, or stenoses in all three epicardial coronary arteries $\geq 50\%$ (Ragosta et al., 2006; Ruzsa et al., 2011).

3.3 | Pressure ulcers risk assessment

Patients who met at least one of the following conditions were deemed as those with underlying risks of pressure ulcers and received further pressure ulcers risk assessment (Qaseem et al., 2015): those older than 60 years old, bedridden for more than 3 days and needing assistance to turn over; malnourished patients whose serum albumin < 30 g/L; patients with medical disorders of consciousness; those with defecate incontinence or urinary incontinence but without urinary catheter placement; those with hemiplegia, paraplegia and other movement disorders; patients with already existed pressure ulcers; those with other risk factors for pressure ulcers, such as requiring forced postures in a specific clinical setting. Pressure ulcers risk was assessed with Braden risk assessment scale, which was based on the dimensions of sensory perception, skin moisture, mobility, nutrition state, friction and shear force. The lower the Braden score, the higher the risk of pressure ulcers. In this study, pressure ulcers score ≥ 15 indicated low-risk group, 13 ~ 14 indicated

medium-risk group, and ≤ 12 indicated high-risk group ("<http://www.education.woundcarestrategies.com/coloplast/resources/BradenScale.pdf>," Accessed May 15, 2020).

3.4 | Statistical analysis

All statistical analyses were performed using IBM SPSS Statics 20. Continuous variables with normal distribution were compared using analysis of variance. If the data did not conform to normal distribution, Wilcoxon rank-sum test was used for analysis. Categorical variables were analysed using chi-square test. Baseline characteristics, cardiovascular risk factors and nursing scores (i.e. Braden score, fall risk score and self-care score) were compared among patients with different severity of coronary artery stenoses. Univariate and multivariate regression analysis were used to identify the predictors of left main or three-vessel disease. Variables with p value $< .1$ in univariate analysis were entered into further multivariate analysis. Receiver operating curve (ROC) analysis was conducted and the cut-off point was tested for investigating the diagnostic value of Braden score to exclude left main or three-vessel disease. Two-sided p value $< .05$ was considered statistically significant.

4 | RESULTS

A total of 193 patients were recruited in the study. Baseline characteristics of study population are listed in Table 1. Coronary angiography revealed non-obstructive coronary atherosclerosis in 19(9.8%) patients, single-vessel or double-vessel stenosis in 113(58.5%) patients and left main or triple-vessel lesions in 61(31.6%) patients. Patients with more severe coronary stenoses had inferior nursing scores at admission [lower Braden scores (control group versus single- or two-vessel disease group versus left main or three-vessel disease group: 16.3 ± 1.6 versus 14.8 ± 2.1 versus 14.0 ± 1.8 , $p < .001$), higher fall risk scores (2.9 ± 1.2 versus 3.3 ± 1.5 versus 3.9 ± 1.7 , $p = .021$), lower self-care scores (45.5 ± 29.6 versus 33.1 ± 17.7 versus 31.3 ± 16.2 , $p = .014$)] and had higher proportion of chronic conditions which contributed to CAD (higher proportion of diabetes or chronic kidney disease, and higher levels of serum creatinine levels) (Figure 1). Patients with multi-vessels coronary disease had lower BMI, longer length of stay, and higher percentage of moderate-to-severe coronary artery calcification. Stratified by pressure ulcers risk, the proportion of patients with high risk was 5.3%, 18.6% and 29.5%, respectively, in control, single- or two-vessel disease, and left main or three-vessel disease group ($p = .025$), indicating that pressure ulcers risk increased as severity of coronary artery stenoses increased.

On univariate regression analysis, a higher risk of left main and three-vessel lesions was associated with Braden score (OR 0.774; 95% CI 0.660–0.907; $p = .002$), age (OR 1.029; 95% CI 1.004–1.055; $p = .021$), BMI (OR 0.901; 95% CI 0.814–0.997; $p = .044$), concomitant diabetes (OR = 2.002; 95% CI 1.053–3.805, $p = .034$), chronic

TABLE 1 Baseline characteristics of the included patients

| Variables | Control group (N = 19) | Single- or two-vessel disease (N = 113) | Left main or three-vessel disease (N = 61) | p value |
|------------------------------------|------------------------|-----------------------------------------|--------------------------------------------|---------|
| Age (years) | 65.4 ± 11.8 | 66.0 ± 13.9 | 70.7 ± 12.6 | .063 |
| Male | 13 (68.4) | 91 (80.5) | 43 (70.5) | .239 |
| BMI (kg/m ²) | 25.4 ± 2.5 | 24.3 ± 3.1 | 23.5 ± 3.2 | .044 |
| Smoking history | 11 (57.9) | 66 (58.4) | 32 (52.5) | .745 |
| Hypertension | 7 (36.8) | 62 (54.9) | 39 (63.9) | .108 |
| Diabetes | 1 (5.3) | 33 (29.2) | 25 (41.0) | .011 |
| Prior stroke | 1 (5.3) | 6 (5.3) | 4 (6.6) | .942 |
| Chronic kidney disease | 0 (0) | 5 (4.4) | 10 (16.4) | .007 |
| COPD | 1 (5.3) | 8 (7.1) | 3 (4.9) | .836 |
| Hospitalization days, median [IQR] | 3 (3–4) | 4 (3–6) | 6 (4–10) | .001 |
| Braden score | 16.3 ± 1.6 | 14.8 ± 2.1 | 14.0 ± 1.8 | <.001 |
| Pressure ulcers risk | | | | |
| Low | 16 (84.2) | 71 (62.8) | 28 (45.9) | .025 |
| Medium | 2 (10.5) | 21 (18.6) | 15 (24.6) | |
| High | 1 (5.3) | 21 (18.6) | 18 (29.5) | |
| Fall risk score | 2.9 ± 1.2 | 3.3 ± 1.5 | 3.9 ± 1.7 | .021 |
| Fall risk | | | | |
| Low | 14 (73.7) | 65 (57.5) | 26 (42.6) | .035 |
| High | 5 (26.3) | 48 (42.5) | 35 (57.4) | |
| Self-care score | 45.5 ± 29.6 | 33.1 ± 17.7 | 31.3 ± 16.2 | .014 |
| Self-care ability | | | | |
| Low | 6 (31.6) | 17 (15.0) | 12 (19.7) | .241 |
| High | 13 (68.4) | 96 (85.0) | 49 (80.3) | |
| LDL (mmol/L) | 2.9 ± 1.2 | 2.8 ± 1.3 | 2.7 ± 0.9 | .875 |
| Creatinine (μmol/L) | 75.3 ± 17.1 | 87.6 ± 54.6 | 111.1 ± 62.3 | .013 |
| Coronary artery calcification | 1 (5.3) | 6 (5.3) | 14 (23.0) | .002 |

Note: Data are mean ± standard deviation or N (%) unless otherwise specified.

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; LDL, low-density lipoprotein cholesterol.

kidney disease (OR = 4.980; 95% CI 1.622–15.289; $p = .005$). After adjusting for age, BMI, diabetes and chronic kidney disease, multivariable analysis showed that Braden score (OR = 0.828; 95% CI 0.696–0.985, $p = .033$) remained significantly associated with left main and three-vessel lesions (Table 2).

ROC analysis showed that Braden score had an area under the curve (AUC) value of 0.645 (95% CI 0.564–0.726, $p = .001$) for excluding more severe coronary artery disease (left main or three-vessel disease) (Figure 2). Furthermore, Braden score of 15.5 was the optimal cut-off value, with the sensitivity and specificity of 78.7% and 42.4%, respectively.

5 | DISCUSSION

The present study investigated the relationship between pressure ulcers risk and the severity of coronary artery stenosis confirmed

by invasive coronary angiography. After adjusting for traditional cardiovascular risk factors, patients with higher risk pressure ulcers had a greater likelihood to have a coronary angiography results showing left main or three-vessel disease. Moreover, Braden score had a high sensitivity for excluding more severe coronary artery disease, indicating that it was conducive to screen patients with chest pain and predict the severity of CAD.

Pressure ulcers refer to local skin and subcutaneous soft tissue injury caused by persistent and intense stimulus of stress and shear force, which often occur in the bony prominences or the site stimulated by medical equipments (Mervis & Phillips, 2019b). Although significant attention has been paid to pressure ulcers prevention by medical institutions at all levels, nearly three million patients suffer from pressure ulcers each year in the US (Mervis & Phillips, 2019a). The correlation between pressure ulcers risk and severity of coronary artery stenosis may be explained by the following reasons. Firstly, patients with obstructive CAD are often accompanied by atherosclerosis

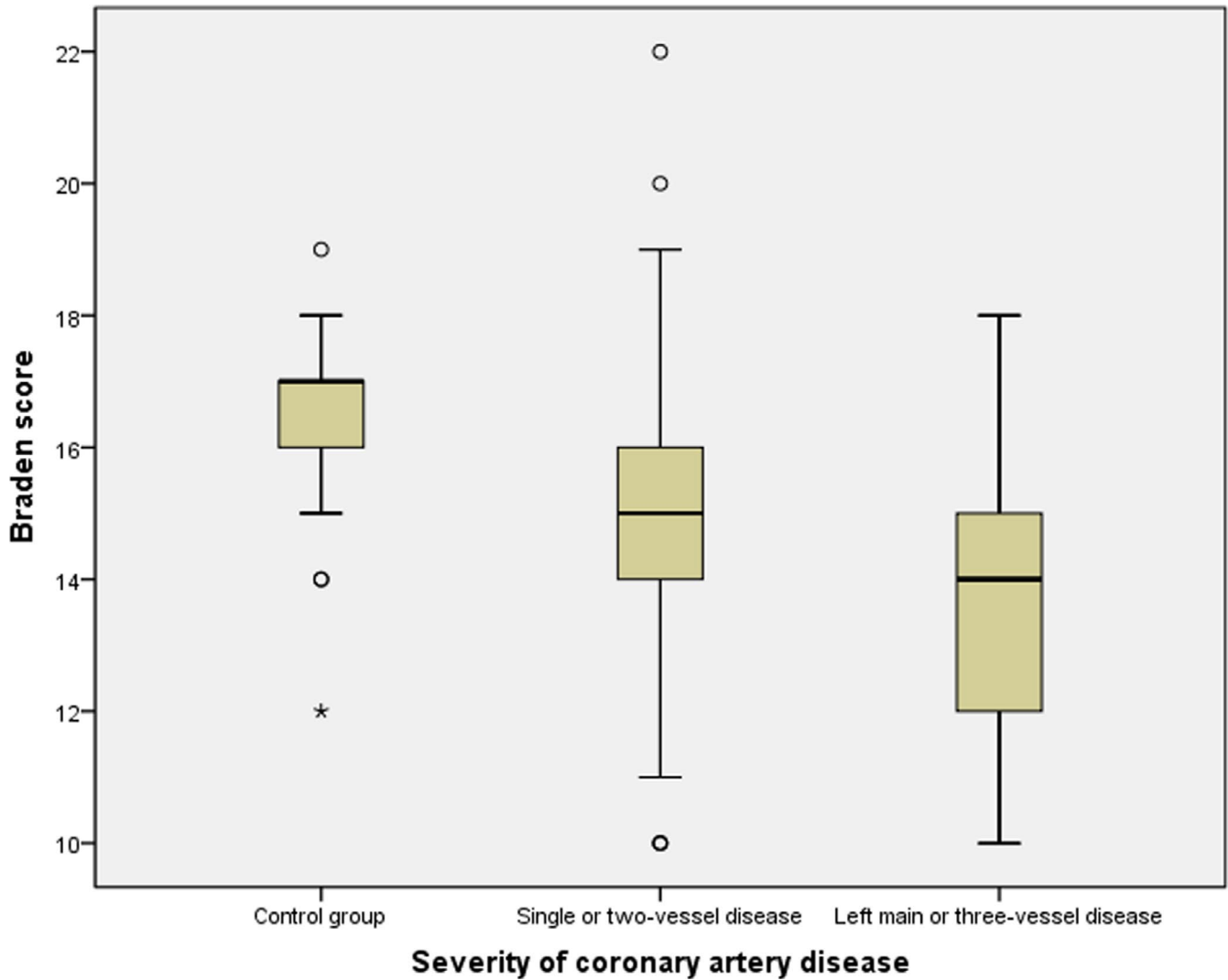


FIGURE 1 Box plot of Braden scores across different severity of CAD

| Variables | Univariate | | Multivariate | |
|------------------------|----------------------|----------------|---------------------|----------------|
| | OR (95% CI) | <i>p</i> value | OR (95% CI) | <i>p</i> value |
| Braden score | 0.774 (0.660–0.907) | .002 | 0.828 (0.696–0.985) | .033 |
| Age | 1.029 (1.004–1.055) | .021 | 1.010 (0.982–1.039) | .498 |
| Male | 0.643 (0.322–1.283) | .21 | | NA |
| BMI | 0.901 (0.814–0.997) | .044 | 0.941 (0.838–1.056) | .304 |
| Smoking history | 0.788 (0.428–1.451) | .444 | | NA |
| Hypertension | 1.619 (0.867–3.022) | .131 | | NA |
| Diabetes | 2.002 (1.053–3.805) | .034 | 1.792 (0.872–3.684) | .113 |
| Chronic kidney disease | 4.980 (1.622–15.289) | .005 | 2.812 (0.833–9.492) | .096 |

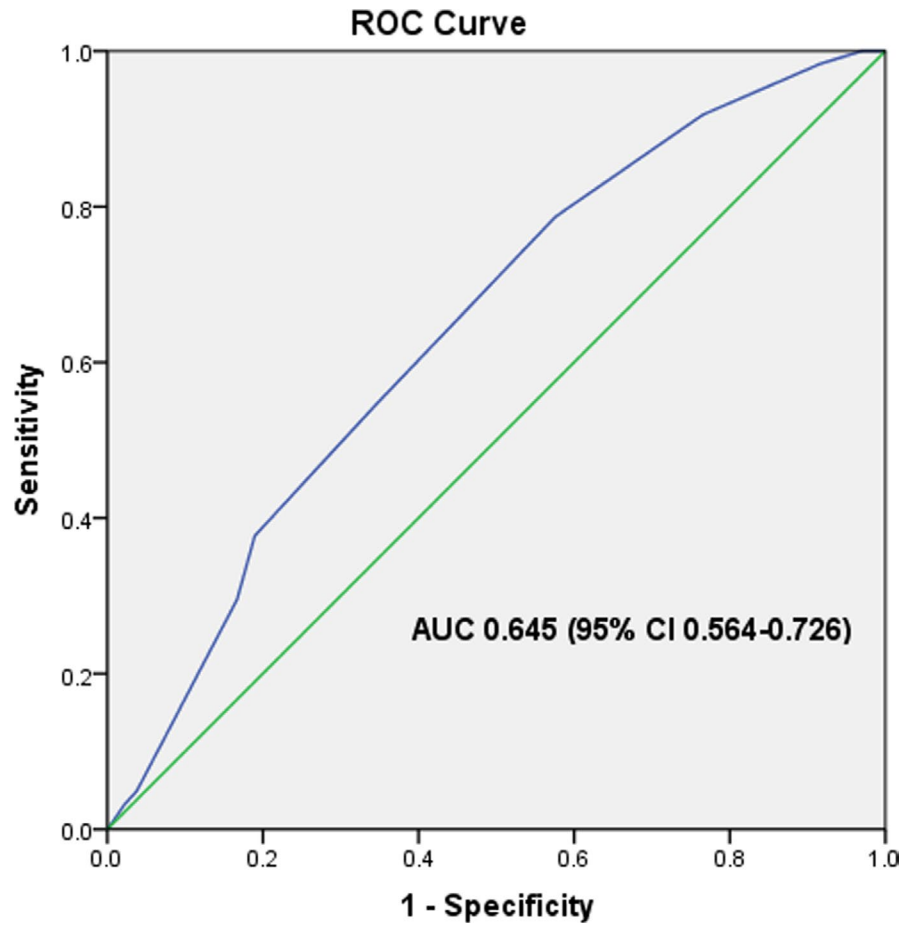
Abbreviations: BMI, body mass index; OR, odds ratio.

TABLE 2 Univariate and multivariate analysis of predictors of left main or three-vessel disease

in multiple vascular beds (Moussa et al., 2009), which may influence blood perfusion and oxygen supply of skin and subcutaneous tissues, leading to skin and soft tissue ischaemia. Secondly, patients with severe

obstructive CAD may be concomitant with ischaemic cardiomyopathy and heart failure; (Squeri et al., 2012) in that case, reduced output of the heart contributes to hypotension and low perfusion of skin tissue,

FIGURE 2 ROC curves by Braden scores for left main or three-vessel disease probability. AUC, area under the curve



facilitating incidence of pressure ulcers. Thirdly, pressure ulcers and CAD share common risk factors such as diabetes, hypertension and smoking; while diabetes would lead to microvascular disease, diabetic nephropathy or diabetic foot, all of which make patients are prone to suffer from pressure ulcers. Therefore, patients with a higher risk of pressure ulcers also have a higher possibility to get more severe CAD.

6 | LIMITATIONS

This study has some limitations. First of all, this is a cross-sectional study which cannot illuminate causal relationship between risk of pressure ulcers and severity of obstructive CAD. It is not prudently to say that severe coronary artery stenosis directly leads to pressure ulcers or pressure ulcers aggravate the coronary artery stenosis. Secondly, this study has certain selection bias. The research just included patients with underlying risk of pressure ulcers who received admission evaluation but not all hospitalized patients undergoing coronary artery angiography, accounting for about 30 per cent of the patients who receiving angiography at that time. Lastly, we acknowledge that pressure ulcers assessment is only moderately predictive of CAD; however, we expect that this non-invasive evaluation could assist in the identification of 'true CAD patients' in the population with suspected CAD and those who benefit mostly from invasive coronary angiography.

7 | CONCLUSIONS

In patients planning to undergo coronary angiography, adding pressure ulcers risk assessment into traditional risk prediction model may improve the positive yield of coronary angiography; besides, pressure ulcers risk evaluation is conducive to predict severity of coronary artery lesions. Larger prospective studies are required in the future to confirm the significance of incorporating pressure ulcers risk into management of patients with suspected CAD.

8 | RELEVANCE TO CLINICAL PRACTICE

Pressure ulcer is a mirror reflecting the inner health of the body. As a routine assessment tool in nursing care in daily practice, pressure ulcers assessment may be conducive to improve the accuracy pre-test probabilities of CAD in patients planning to undergo coronary angiography. On the other hand, patients with higher pressure ulcers risk should be carefully evaluated for their coronary artery health.

CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

Study concept and design: Wang, Yang, Huang. Acquisition, analysis, or interpretation of data: All authors. Drafting of the manuscript: Wang, Chen R, Ding, Huang. Critical revision of the manuscript for important intellectual content: All authors. Obtained funding: Huang. Study supervision: Huang.

DATA AVAILABILITY STATEMENT

The data sets analysed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Wang Y, Chen R, Ding J, Yang L, Chen J, Huang B. Predictive value of pressure ulcer risk for obstructive coronary artery disease. *Nurs Open*. 2021;8:1848–1855. <https://doi.org/10.1002/nop2.835>