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World Journal of Clinical Cases

Contents

Thrice Monthly Volume 10 Number 12 April 26, 2022

EVIDENCE REVIEW

3639 Tilt and decentration with various intraocular lenses: A narrative review

Chen XY, Wang YC, Zhao TY, Wang ZZ, Wang W

REVIEW

3647 Role of zonula occludens in gastrointestinal and liver cancers

Ram AK, Vairappan B

MINIREVIEWS

3662 Pathophysiological mechanisms of hepatic stellate cells activation in liver fibrosis

Garbuzenko DV

ORIGINAL ARTICLE

Retrospective Cohort Study

3677 Predictors of unfavorable outcome at 90 days in basilar artery occlusion patients

Chiu YC, Yang JL, Wang WC, Huang HY, Chen WL, Yen PS, Tseng YL, Chen HH, Tsai ST

Retrospective Study

3686 Role of multidetector computed tomography in patients with acute infectious colitis

Yu SJ, Heo JH, Choi EJ, Kim JH, Lee HS, Kim SY, Lim JH

3698 Efficacy and prognostic factors of neoadjuvant chemotherapy for triple-negative breast cancer

Ding F, Chen RY, Hou J, Guo J, Dong TY

3709 Relationship between subgroups of central and lateral lymph node metastasis in clinically node-negative papillary thyroid carcinoma

Zhou J, Li DX, Gao H, Su XL

3720 Nomogram to predict postoperative complications in elderly with total hip replacement

Tan XJ, Gu XX, Ge FM, Li ZY, Zhang LQ

3729 Flap failure prediction in microvascular tissue reconstruction using machine learning algorithms

Shi YC, Li J, Li SJ, Li ZP, Zhang HJ, Wu ZY, Wu ZY

Observational Study

3739 Surgery in platinum-resistant recurrent epithelial ovarian carcinoma

Zhao LQ, Gao W, Zhang P, Zhang YL, Fang CY, Shou HF

World Journal of Clinical Cases

Thrice Monthly Volume 10 Number 12 April 26, 2022

Contents

3754 Anorectal dysfunction in patients with mid-low rectal cancer after surgery: A pilot study with three-dimensional high-resolution manometry

Pi YN, Xiao Y, Wang ZF, Lin GL, Qiu HZ, Fang XC

Randomized Controlled Trial

3764 Effect of wrist-ankle acupuncture on propofol dosage during painless colonoscopy: A randomized controlled prospective study

He T, Liu C, Lu ZX, Kong LL, Li Y, Xu Z, Dong YJ, Hao W

META-ANALYSIS

3773 Melatonin intervention to prevent delirium in hospitalized patients: A meta-analysis

You W, Fan XY, Lei C, Nie CC, Chen Y, Wang XL

3787 Risk factors for hospital readmissions in pneumonia patients: A systematic review and meta-analysis

Fang YY, Ni JC, Wang Y, Yu JH, Fu LL

CASE REPORT

3801 Anti-programmed death 1 antibody in the treatment of coexistent *Mycobacterium fortuitum* and lung cancer: A case report

Zhang CC, Chen P

3808 Acute pancreatitis-induced thrombotic thrombocytopenic purpura: A case report

Wang CH, Jin HF, Liu WG, Guo Y, Liu Z

3814 Successful management of life-threatening aortoesophageal fistula: A case report and review of the literature

Zhong XQ, Li GX

3822 Isolated coagulopathy without classic CRAB symptoms as the initial manifestation of multiple myeloma: A case report

Zhang Y, Xu F, Wen JJ, Shi L, Zhou QL

3828 Evaluation of intracoronary function after reduction of ventricular rate by esmolol in severe stenotic myocardial bridge: A case report

Sun LJ, Yan DG, Huang SW

3834 Pediatric living donor liver transplantation using liver allograft after *ex vivo* backtable resection of hemangioma: A case report

Li SX, Tang HN, Lv GY, Chen X

3842 Kimura's disease in soft palate with clinical and histopathological presentation: A case report

Li W

3849 Combined targeted therapy and immunotherapy in anaplastic thyroid carcinoma with distant metastasis: A case report

Ma DX, Ding XP, Zhang C, Shi P

World Journal of Clinical Cases

Thrice Monthly Volume 10 Number 12 April 26, 2022

Contents

3856 Successful multimodality treatment of metastatic gallbladder cancer: A case report and review of literature

Zhang B, Li S, Liu ZY, Peiris KGK, Song LF, Liu MC, Luo P, Shang D, Bi W

3866 Ischemic colitis after receiving the second dose of a COVID-19 inactivated vaccine: A case report

Cui MH, Hou XL, Liu JY

3872 Cryoballoon pulmonary vein isolation and left atrial appendage occlusion prior to atrial septal defect closure: A case report

Wu YC, Wang MX, Chen GC, Ruan ZB, Zhang QQ

3879 Surgical treatment for a combined anterior cruciate ligament and posterior cruciate ligament avulsion fracture: A case report

Yoshida K, Hakozaki M, Kobayashi H, Kimura M, Konno S

3886 Successful robot-assisted partial nephrectomy for giant renal hilum angiomyolipoma through the retroperitoneal approach: A case report

Luo SH, Zeng QS, Chen JX, Huang B, Wang ZR, Li WJ, Yang Y, Chen LW

3893 Cryptococcal antigen testing of lung tissue homogenate improves pulmonary cryptococcosis diagnosis: Two case reports

Wang WY, Zheng YL, Jiang LB

3899 Combined use of extracorporeal membrane oxygenation with interventional surgery for acute pancreatitis with pulmonary embolism: A case report

Yan LL, Jin XX, Yan XD, Peng JB, Li ZY, He BL

3907 Dynamic navigation system-guided trans-inferior alveolar nerve implant placement in the atrophic posterior mandible: A case report

Chen LW, Zhao XE, Yan Q, Xia HB, Sun Q

3916 Anti-glomerular basement membrane disease with IgA nephropathy: A case report

Guo C, Ye M, Li S, Zhu TT, Rao XR

3923 Amniotic membrane transplantation in a patient with impending perforated corneal ulcer caused by *Streptococcus mitis*: A case report and review of literature

Hsiao FC, Meir YJJ, Yeh LK, Tan HY, Hsiao CH, Ma DHK, Wu WC, Chen HC

3930 Steriod for Autoimmune pancreatitis complicating by gastric varices: A case report

Hao NB, Li X, Hu WW, Zhang D, Xie J, Wang XL, Li CZ

3936 Antithrombotic treatment strategy for patients with coronary artery ectasia and acute myocardial infarction: A case report

Liu RF, Gao XY, Liang SW, Zhao HQ

3944 Mesh plug erosion into the small intestine after inguinal hernia repair: A case report

Xie TH, Wang Q, Ha SN, Cheng SJ, Niu Z, Ren XX, Sun Q, Jin XS

3951 Recurrence of infectious mononucleosis in adults after remission for 3 years: A case report

Zhang XY, Teng QB

3959 Vertical direction impaction of kissing molars: A case report

Wen C, Jiang R, Zhang ZQ, Lei B, Yan YZ, Zhong YQ, Tang L

LETTER TO THE EDITOR

3966 Comment on "Outcomes of different minimally invasive surgical treatments for vertebral compression fractures: An observational study"

Ma L, Luo ZW, Sun YY

World Journal of Clinical Cases

Thrice Monthly Volume 10 Number 12 April 26, 2022

Contents

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ORIGINAL ARTICLE

Retrospective Study

Nomogram to predict postoperative complications in elderly with total hip replacement

Xiu-Juan Tan, Xiao-Xia Gu, Feng-Min Ge, Zhi-Yi Li, Liang-Qing Zhang

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Abstract

BACKGROUND

By analyzing the risk factors of postoperative complications in elderly patients with hip replacement, We aimed to develop a nomogram model based on preoperative and intraoperative variables and verified the sensitivity and specificity for risk stratification of postoperative complications in elderly with total hip replacement patients.

AIM

To develop a nomogram model for risk stratification of postoperative complications in elderly with total hip replacement patients.

METHODS

A total of 414 elderly patients who underwent surgical treatment for total hip replacement hospitalized at the Affiliated Hospital of Guangdong Medical University from March 1, 2017 to August 31, 2019 were included into this study. Univariate and multivariate logistic regression were conducted to identify independent risk factors of postoperative complication in the 414 patients. A nomogram was developed by R software and validated to predict the risk of postoperative complications.

RESULTS

Multivariate logistic regression analysis revealed that age (OR = 1.05, 95%CI: 1.00-1.09), renal failure (OR = 0.90, 95%CI: 0.83-0.97), Type 2 diabetes (OR = 1.05, 95%CI: 1.00-1.09), albumin (ALB) (OR = 0.91, 95%CI: 0.83-0.99) were independent risk factors of postoperative complication in elderly patients with hip replacement ($P < 0.05$). For validation of the nomogram, receive operating characteristic curve

revealed that the model predicting postoperative complication in elderly patients with hip replacement was the area under the curve of 0.8254 (95%CI: 0.78-0.87), the slope of the calibration plot was close to 1 and the model passed Hosmer-Lemeshow goodness of fit test (χ^2 = 10.16, P = 0.4264), calibration in R E_{max} = 0.176, E_{avg} = 0.027, which all demonstrated that the model was of good accuracy.

CONCLUSION
The nomogram predicting postoperative complications in patients with total hip replacement constructed based on age, type 2 diabetes, renal failure and ALB is of good discrimination and accuracy, which was of clinical significance.

Key Words: Elderly; Total hip replacement; Postoperative complication; Nomogram

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Core Tip: Predictive models refer to the use of multivariate methods in the design and analysis of prognostic studies to identify important predictors of outcomes and to provide a combination of outcome probabilities or tools for estimating such probabilities. Predictive models can be used in a variety of medical settings, primarily to predict the course (or risk) of an individual disease, and to guide doctors and patients in deciding together on further treatment. This study aims to establish prediction model of postoperative complications in elderly patients with total hip replacement is use individualized treatment to assist complex decision-making.

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INTRODUCTION

Hip replacement is a frequently done and highly successful surgical intervention[1]. More than one million hip arthroplasties are performed annually worldwide[2]. Kurtz *et al*[3] projected the demand for primary total hip arthroplasty (THA) to grow 174% to 572000 procedures per year by 2030. These procedures carry a complication rate estimated to be between 2% and 14%; higher complication rates are associated with more elderly and comorbid patient populations[4]. Numerous clinical tools have been developed to predict a variety of THA patient outcomes[5-7], but the risk calculator to be a poor predictor of postoperative complications in Chinese. This is likely due to the complexity of the environment, race and personal differences. As an anesthetist, when we go to the inpatient ward for preoperative evaluation, patient often ask: what is the proportion of risk in my surgery? The answer is perhaps or we don't know. So we want to create a tool not only can predict the risk precisely, but also guide the clinical work. Therefore this study will analyze clinical data, explored the independent risk factors for postoperative complications in elderly patients undergoing total hip replacement, develop a nomogram for accurate risk stratification of postoperative complications based on preoperative and intraoperative variables, and verify whether this tool would have good predictive for patients undergoing total hip replacement in our hospital.

MATERIALS AND METHODS

Patients

Approved by the Ethics Committee of the Affiliated Hospital of Guangdong Medical University committee (PJ2020-022), we were collected from all patients undergoing total hip replacement from March 1, 2017 to August 31, 2019 at the Affiliated Hospital of Guangdong Medical University. Inclusion criteria were age > 65 years, elective surgical treatment with total hip replacement. Non-inclusion criteria were age < 65 years, electronic medical records incomplete, patients or family members disagree with the study.

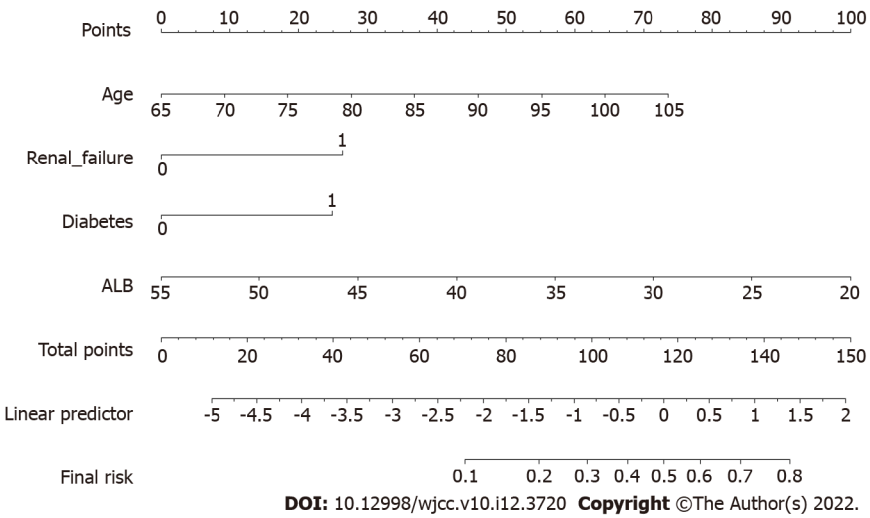

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Figure 1 Nomogram. The Morbidity and Mortality Acute Predictor (arthro-MAP). The nomogram computes the probability of having a postoperative complication. In order to compute the predicted complication probability, a vertical line is to be drawn from the values of the individual variables to the scale for points on the top. Then a vertical line from the total points to the corresponding predicted complication probability.

Research methods

Data on general patient information, comorbidities, laboratory test results, intraoperative variables, and postoperative complications during hospitalization were collected from electronic medical records and electronic Anesthesia Information Management System. Known patient-related factors of complications are age, gender, fractures or not and comorbidity such as renal failure, hypertension, diabetes, coronary heart disease, stroke, laboratory test results of white blood cells, red blood cells, hemoglobin, platelets, albumin (ALB) and blood urea nitrogen. Intraoperative variables included estimated blood loss, lowest heart rate, the type of anesthesia, preoperative American Society of Anesthesiologists Score and operation time.

The primary outcome measure was the incidence of a postoperative complication or death during hospitalization. Complications were identified from diagnoses in discharge summaries, operative reports, and International Classification of Diseases-9 codes by a single investigator. Included: cardiac arrest, deep venous thrombosis, myocardial infarction, pneumonia, pulmonary embolism, systemic inflammatory response syndrome, infection, dislocation, delirium, according to definitions from the National Quality Improvement Project[8].

Statistical analysis

All statistical analyses were performed using the STATA14.0 statistical software package and R software (R3.2.3) with rms package added. Differences between patients with and without complications were compared with t-test or Wilcoxon rank-sum test using the mean ± SD and the median (range) for quantitative variables and chi-squared test using n (%) for qualitative variables. Univariate logistic regression for patients clinical data were analyzed to identify the independent risk factors for postoperative complications after surgery. A multivariate logistic regression model was built using the factors associated with P values < 0.05 by univariate analysis. Selection values of $P < 0.05$ variables by multivariate analysis to create a nomogram model by R software (R3.2.3) rms package, evaluated the nomogram by assessing discrimination and calibration.

RESULTS

In our study 414 elderly total hip replacement patients of 59 cases with postoperative complications after surgery, the incidence was 14.3%. The demographics and descriptive statistics for our patient cohort are given in Table 1. Multivariable logistic regression of each clinical variable of patients related factors for postoperative complications include patients age (OR = 1.05, 95%CI: 1.00-1.09), renal failure (OR = 0.90, 95%CI: 0.83-0.97), diabetes (OR = 2.37, 95%CI: 1.04-5.40) and ALB (OR = 0.91, 95%CI: 0.83-0.99) (Table 2).

According to the above multivariable logistic regression analysis results, choose $P < 0.05$ variable apply R software to build a nomogram model of postoperative complications in elderly total hip replacement patients (Figure 1).

Using nomogram model to predict postoperative complications in elderly total hip replacement patients risk receive operating characteristic (ROC) curve, area under curve (AUC) is 0.8254 (95%CI:

Table 1 Comparison of clinical data between no complications and complications

Patient characteristics	No complications (*n* = 355)	Complications (*n* = 59)	*t*/χ^2/Z value	*P* value
Age (yr)[1]	74.06 ± 7.25	81.29 ± 8.19	6.96	0.000
Male gender (%)[2]	149 (41.9)	24(40.7)	0.03	0.852
Weight (kg)[1]	58.93 ± 10.23	57.2 ± 9.93	1.2	0.226
Comorbidities				
Hypertension (%)[2]	114 (32.1)	30 (50.8)	7.83	0.006
Diabetes (%)[2]	50 (14.1)	16 (27.1)	6.41	0.017
Coronary heart disease (%)[2]	30 (5)	10 (16.9)	4.19	0.041
Stroke (%)[2]	16 (4.5)	12 (20.3)	20.11	0.000
Renal failure (%)[2]	13 (3.7)	7 (11.9)	7.404	0.017
Fractures (%)[2]	123 (34.6)	45 (76.3)	36.35	0.000
Laboratory data				
WBC (10^9/L)[1]	7.6 ± 2.46	8.69 ± 2.93	2.7	0.003
RBC (10^{12}/L)[1]	4.21 ± 0.59	3.89 ± 0.69	3.81	0.000
Hb (g/L)[1]	123.37 ± 20.99	111.89 ± 22.64	3.85	0.000
PLT (10^9/L)[1]	235.66 ± 71.56	247.91 ± 115.27	0.79	0.272
ALB (g/L)[1]	39.37 ± 4.51	35.75 ± 4.41	5.72	0.000
BUN (mmol/L)[1]	6.05 ± 4.02	7.71 ± 5.08	2.39	0.019
Intraoperative characteristics				
EBL (mL)[3]	203.79 (50-1500)	229.8 (50-1000)	1.5	0.134
Lowest heart rate (bpm)[1]	59.39 ± 10.49	65.37 ± 13.88	3.16	0.001
Operation time (min)[1]	100.85 ± 40.26	89.41 ± 37.24	2.04	0.505
General anesthesia (%)[2]	159 (44.8)	24 (40.7)	0.35	0.556
ASA class III or IV (%)[2]	159 (44.8)	518 (86.4)	39.35	0.000

[1]*t* test;
[2]Chi-square test;
[3]Wilcoxon rank-sum test.
Preoperative patient characteristics for 414 total hip replacement procedures between March 1, 2017 and August 31, 2019. Results are presented as number (percentage) of patients, or as mean ± SD. The *P* values were obtained from chi-square tests, t-tests, or Wilcoxon rank-sum tests, as indicated. EBL: Estimated blood loss; ASA: American Society of Anesthesiologists.

0.78-0.87), indicating that the nomogram model has a good bootstrap-corrected concordance (Figure 2).

Perform Hosmer-Lemeshow goodness-of-fit test and evaluate nomogram Model accuracy, Hosmer-Lemeshow fit goodness test $\chi^2 = 10.16$, $P = 0.4264$ (Figure 3), calibration in rms package by R software $E_{max} = 0.176$, $E_{avg} = 0.027$ (Figure 4), all shows that the model appears to be well-calibrated, with predicted outcome rates closely reflecting the observed rates.

DISCUSSION

China is the most populated country in the world, and now has the second-largest economy in the world[9]. As nearly 166 million Chinese are aged more than 65 years[10]. The demand for healthcare, including hip arthroplasty is increasing[11,12]. There are several predict complications model have be reported[13-15], but on one is modeling by Chinese. In this study, 59 of the 414 elderly total hip replacement patients who underwent surgical treatment were developed postoperative complication, the incidence is 14.3%, morbidity is much higher than 3.9%[16]. Probably because our definition of complications not only included dislocation, pulmonary embolism, and infection as reported previously, but included systemic inflammatory response syndrome, delirium which are common in elderly. Among 566 older patients (mean age, 76.7 years) undergoing a variety of elective operations

Table 2 Multivariable logistic regression analysis results

Variables	OR	SE	Z	95%CI	*P* value
Age	1.05	0.02	2.04	1.00-1.09	0.041
Renal failure	3.96	2.44	2.23	1.18-13.27	0.026
Hypertension	1.31	0.47	0.74	0.65-2.64	0.457
Coronary heart disease	0.84	0.41	0.36	0.32-2.18	0.722
Diabetes	2.37	1.00	2.05	1.04-5.40	0.040
Stroke	2.41	1.15	1.84	0.94-6.16	0.066
Fractures	2.21	0.95	1.86	0.96-5.12	0.063
ASA class III or IV	1.85	0.68	1.69	0.91-3.79	0.090
Lowest heart rate	1.02	0.01	1.10	0.99-1.05	0.272
RBC	1.05	0.34	0.16	0.56-1.99	0.869
WBC	1.03	0.64	0.44	0.91-1.16	0.657
Hb	1.00	0.01	0.10	0.98-1.02	0.922
ALB	0.90	0.04	2.73	0.83-0.97	0.006
BUN	1.00	0.04	0.13	0.94-1.08	0.893

RBC: Red blood cell; WBC: White blood cell; Hb: Hemoglobin; ALB: Albumin; BUN: Blood urea nitrogen; ASA: American Society of Anesthesiologists.

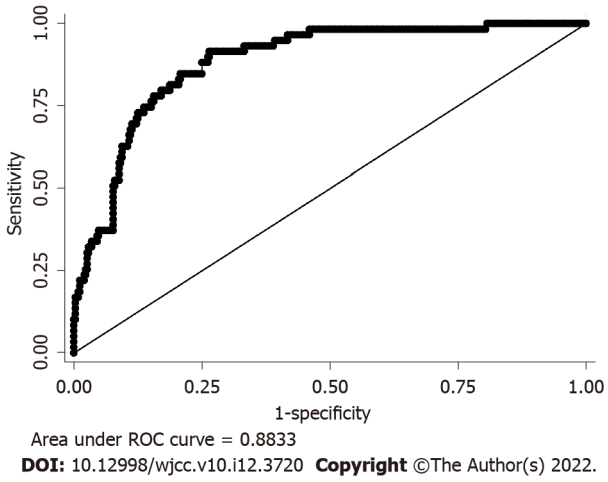

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Figure 2 Receive operating characteristic curve. It also name sensitivity curve, the area under curve (AUC) can evaluate the nomogram model discrimination degree. AUC > 0.6: May make sence; AUC > 0.7: Not bad; AUC > 0.8: Excellent. ROC: Receive operating characteristic; AUC: Area under curve.

(including orthopedic, general, and vascular), 23.9% patients developed postoperative delirium[17]. The incidence of postoperative delirium was reported as 7.0%-30.2% in hip arthroplasty[18,19]. In this study the average age is 75.09 ± 7.8. As a result, the morbidity 14.3% is considered to be reasonable.

Age is a recognized risk factor for postoperative complications. The results of this study indicate that elderly patients with renal failure and diabetes are more likely to have postoperative complications after total hip replacement. It is Consistent with the research results of Merrill *et al*[20]. One possible reason is that elderly patients have more comorbidities will make them less able to withstand the stresses of anesthesia and surgery[21,22]. Diabetes have been reported to be significant predictors for complications such as surgical site infections[23]. The available data suggest that diabetes may promote the development of osteoarthritis[24]. Our results for the outcome measure indicate that elderly patients with renal failure and diabetes increase the weight of the nomogram model score by 25 points and 24 points, respectively.

Interestingly, our data suggest that low preoperative albumin levels can predict the incidence of postoperative complications following surgery for total hip replacement. The result is consistent with Kishawi *et al*[25]. Since ALB is a biomarker of visceral protein and immune-competence status, it is commonly used for nutritional assessment[26]. Preoperative albumin bears strong potential as a

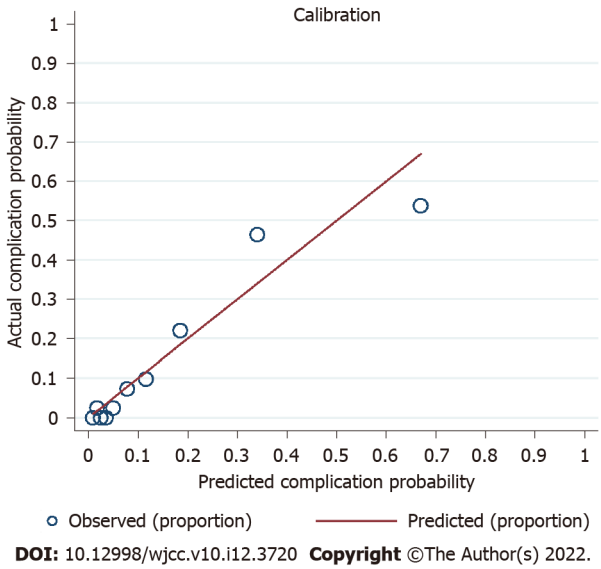

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Figure 3 Hosmer-Lemeshow test. The null hypothesis is that the fitting probability pi is grouped by 10 decile, and the difference between the fitted value and the observed value in each group, $P < 0.05$ shows that the scatter separation is significantly deviated from the reference line, the predicted value is not equal to the actual value. Otherwise, the test passes, the predicted value is equal to the actual value.

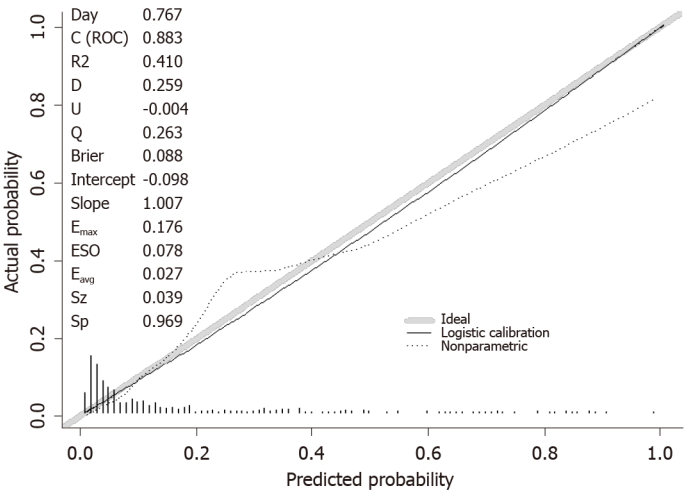

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Figure 4 Calibration plot. A calibration plot compares the model's predicted probabilities and observed proportions. The diagonal line reflects the ideal situation (predicted probability = observed proportion). The curve represents the relation nonparametrically. The calibration curve is a straight line with a slope close to 1, indicating that this model predicts postoperative complication risk in elderly total hip replacement patients consistent with the actual risk.

practical metric to assess a patient's overall health[27]. Recent studies even show that low ALB rather reflects a state of persistent inflammation[28]. The perhaps reason for ALB as an independent predictor of major complications is that ALB recapitulates the physiological stress intensity triggered by surgery, which is determined by several factors, such as the invasiveness of surgery and its duration, as well as the intrinsic characteristics of the patient[29]. Our results pointed out that the weight of 12.7 points in the nomogram model score will be increased for every 5 g/L decrease in ALB. We recommend surgeons and anesthetists should ideally attempt to optimize patient nutritional status before total hip replacement in elderly in order to avoid a greater likelihood of postoperative complications or mortality.

However our study has several limitations. First, our data were limited only 414 patients, it only represents an elective patient population. Second, complications were only collected while in hospital, some of these complications could have occurred after discharge. Third, the predict model quality checks only with internal validation, so external validation will have to be included in future studies in order to promote use. Fourth, this was a retrospective study that relied on 9th edition coding, which can lead to errors and/or incomplete coding.

Risk calculators should serve as a tool to help clinical decision-making, promote individualized medicine, and aid in the shared decision-making process[30]. Many of the studies report poor discrimination and calibration of the investigated risk calculators. In our study, founded that age, diabetes,

renal failure, and Albumin value are independent risk factors for postoperative complications in elderly patients with total hip replacement, ROC curve shows the AUC is 0.8254, indicating that the nomogram model has a good discrimination. The Hosmer-Lemeshow fit goodness test $\chi^2 = 10.16$, $P = 0.4264$ and calibration curve is a straight line with a slope close to 1, indicating that the nomogram model has good accuracy in predicting the risk of postoperative complications in elderly patients with total hip replacements surgery and has clinical application value.

CONCLUSION

This study created a nomogram model based on age, diabetes, renal failure, and albumin value independent risk factors for postoperative complications, has good indexing and accuracy can provide scientific guidance for individualized clinical prevention and treatment of postoperative complications in elderly patients with total hip replacements surgery in our hospital. This four variables are easy to get in clinical practice, has clinical application value especially for basic-level hospital.

ARTICLE HIGHLIGHTS

Research background

As living standards and medical technology improve, the average lifespan and demand for medical care are gradually increasing, and the number of total hip replacements in elderly individuals is also increasing. Patients who undergo total hip replacement often experience trauma, pain, bleeding, and immobilization, leading to a cascade of inflammatory and metabolic processes that lead to severe postoperative complications. Numerous clinical tools have been developed to predict a variety of THA patient outcomes, but these risk calculators are poor predictors of postoperative complications in Chinese patients. The aim of this study was to analyse and assess postoperative complications and develop a nomogram model based on the related risk factors in elderly patients who underwent total hip replacement to guide surgeons and anaesthesiologists in developing strategies to minimize complications in elderly patients.

Research motivation

Develop a nomogram model to provide scientific guidance for the individualized prevention and treatment of postoperative complications in elderly patients who underwent total hip replacement.

Research objectives

To develop a nomogram model based on preoperative and intraoperative variables to predict postoperative complications in elderly patients who underwent total hip replacement.

Research methods

We collected the clinical data of all patients who underwent total hip replacement from March 1, 2017 to August 31, 2019 at the Affiliated Hospital of Guangdong Medical University, including patient information, comorbidities, laboratory test results, intraoperative variables, and postoperative complications during hospitalization. The STATA 14.0 statistical software package and R software (R3.2.3) were used to develop a nomogram to predict the risk of postoperative complications in elderly patients who underwent total hip replacement surgery. The nomogram model can predict the risk of adverse clinical events individually by quantifying and visually displaying the results of the logistic regression.

Research results

Age, diabetes, renal failure, and albumin value were independent risk factors for postoperative complications in elderly patients who underwent total hip replacement surgery.

Research conclusions

The nomogram model can integrate the related risk factors and predict the risk of adverse clinical events for individual patients and provide scientific guidance for the individualized clinical prevention and treatment of postoperative complications in elderly patients who underwent total hip replacement surgery.

Research perspectives

We will increase the sample size used to construct the model, perform prolonged follow-up, and conduct a multicenter study in the future.

FOOTNOTES

Author contributions: Tan XJ is first Author, participated in protocol writing, collecting data, statistical analysis, interpretation of results and manuscript writing; Ge FM helped collection of cases; Li ZY participated in protocol writing, essay writing; Gu XX helped interpretation of results and manuscript writing; Zhang LQ did the statistical analysis and reviewed the manuscript.

Institutional review board statement: This study was reviewed and approved by the Ethics Committee of the Affiliated Hospital of Guangdong Medical University with the reference number PJ2020-022.

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