A Nomogram to Predict Postoperative Complications in Elderly with Total Hip Replacement

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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.

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) , Type2 diabetes (OR=1.05, 95% CI: 1.00-1.09) , ALB (OR=0.91, 95% CI: 0.83-0.99) were independent risk factors of postoperative complication in elderly patients with hip replacement ($P \leq 0.05$) . For validation of the nomogram, ROC 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 ($\chi^2 = 10.16$, $P=0.4264$), calibration in R Emax=0.176, Eavg=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.

Background

Hip replacement is a frequently done and highly successful surgical intervention [1]. More than one million hip arthroplasties are performed annually worldwide [2]. Kurtz and colleagues [3] projected the demand for primary THA to grow 174% to 572,000 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], but fewer to predict complications after surgery and no one is modelling by Chinese. 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.

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 > 65y, elective surgical treatment with total hip replacement. Non-inclusion criteria were age < 65y, electronic medical records incomplete, patients or family members disagree with the study.

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 cell (WBC), red blood cell (RBC), hemoglobin (HB), platelets (PLT), albumin (ALB) and blood urea nitrogen (BUN). Intraoperative variables included estimated blood loss (EBL), lowest heart rate, the type of anesthesia, preoperative ASA score (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 ICD-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 NSQIP [6].

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 $\pm$ 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 (Fig. 1).

Using nomogram model to predict postoperative complications in elderly total hip replacement patients risk ROC curve, AUC is 0.8254(95% CI: 0.78~0.87), indicating that the nomogram model has a good bootstrap-corrected concordance(Fig. 2).

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

Table 1
Comparison of clinical data between No Complications and Complications.

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

Preoperative patient characteristics for 414 total hip replacement procedures between March 1, 2017 to August 31, 2019. Results are presented as number (percentage) of patients, or as mean $\pm$ standard deviation. The P values were obtained from chi-square tests, t-tests, or Wilcoxon rank-sum tests, as indicated (a t-test; b chi-square test; c Wilcoxon rank-sum test).

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 I or II	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

Discussion

China is the most populated country in the world, and now has the second-largest economy in the world [7]. As nearly 166 million Chinese are aged more than 65 years [8]. The demand for healthcare, including hip arthroplasty is increasing [9, 10]. There are several predict complications model have be reported [11, 12, 13], 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% [14]. 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 (including orthopedic, general, and vascular), 23.9% patients developed postoperative delirium [15]. The incidence of postoperative delirium

was reported as 7.0%-30.2% in hip arthroplasty [16, 17]. 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 Robert K [18] et al. One possible reason is that elderly patients have more comorbidities will make them less able to withstand the stresses of anesthesia and surgery [19, 20]. Diabetes have been reported to be significant predictors for complications such as surgical site infections [21]. The available data suggest that diabetes may promote the development of osteoarthritis [22]. 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. Since ALB is a biomarker of visceral protein and immune-competence status, it is commonly used for nutritional assessment [23]. Preoperative albumin bears strong potential as a practical metric to assess a patient's overall health [24]. Recent studies even show that low ALB rather reflects a state of persistent inflammation [25]. 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 anesthesiologists 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 [26]. 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.

Conclusions

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. These four variables are easy to get in clinical practice, has clinical application value especially for Basic-level hospital.

Abbreviations

ASA: American Society of Anesthesiologists; THA: Total hip arthroplasty; NSQIP: National Surgical Quality Improvement Program; SD: Standard error; ROC: Receiver operating characteristic curve; AUC: Area under curve

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of the Affiliated Hospital of Guangdong Medical University with the reference number PJ2020-022. All participants were informed and asked for written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study will be available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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No-funding. XJ T and XX G are designer of the study, collecting data, statistical analysis, interpretation of results and writing the manuscript together.

Authors' contributions

XJ T is first Author, participated in protocol writing, collecting data, statistical analysis, interpretation of results and manuscript writing. FM G helped collection of cases. ZY L participated in protocol writing, essay writing. XX G helped interpretation of results and manuscript writing. GX M and LQ Z did the

statistical analysis and reviewed the manuscript. All authors have read and approved the final submitted manuscript.

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Figures

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.

Figure 2

ROC curve. It also name sensitivity curve, the AUC (Area under curve) can evaluate the nomogram model discrimination degree. AUC>0.6: may make sense; AUC>0.7: Not bad; AUC>0.8: Excellent.

Figure 3

Hosmer -Lemeshow test. The null hypothesis is that the fitting probability π 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.

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.