# Validation of the arthro-MAP Nomogram to Predict Major Complications after Hip and Knee Arthroplasty in Chinese Population

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**Research article**

**Keywords:** Hip and Knee Arthroplasty, nomograms, validation studies

**Posted Date:** November 18th, 2020

**DOI:** https://doi.org/10.21203/rs.3.rs-107458/v1



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## Abstract

# Background

A nomogram(arthro-MAP) predict major complications after Hip and Knee Arthroplasty has been establish by England people. The goal of this study is to externally validate the nomogram whether suitable for Chinese people or not.

# Methods

A total of 414 elderly patients with Hip and Knee Arthroplasty underwent surgical treatment in the Affiliated Hospital of Guangdong Medical University from March 1, 2017 to August 31, 2019 were included into this study. Variables assessed were lowest intraoperative HR, EBL, preoperative BUN, procedure type, race, ASA score, comorbidities, presence of fracture. Receiver-operator characteristics (ROC) curve analysis, calibration (HL) and DCA were used to evaluate predictive properties of the nomogram.

# Results

A total of 414 patients were consecutively enrolled. 47 patients (11.35%) presented a major complications after Hip and Knee Arthroplasty. The arthro-MAP nomogram presented an AUC of 0.816; 95%CI: 0.757–0.875 to predict major complications. At the calibration plot $x^2 = 17.13$, $P > 0.05$, means the arthro-MAP nomogram appears to be well-calibrated in Chinese population, with predicted outcome rates closely reflecting the observed rates.

# Conclusions

Although further studies are needed to confirm our results, the arthro-MAP nomogram was, in our experience, an excellent tool to predict major complications after Hip and Knee Arthroplasty, can be perform well in the Chinese population.


## Introduction

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) is a frequently done and highly successful surgical intervention [1]. The procedure is undertaken to relieve pain and improve function in individuals with advanced arthritis of the hip joint. Worldwide, more than 1 million total hip replacements are done each year [2]. Kurtz and colleagues [3] projected the demand for primary THA to grow 174% to 572,000 procedures per year by 2030 in the USA.

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]. In the current environment, accurate risk stratification tools would be of great value to patients, physicians,

payers, and policy makers. Thomas H. Wuerz et al developed a nomogram based on preoperative and intraoperative variables derived from 3511 patients who underwent Hip and Knee Arthroplasty. (Fig. 1) [5]. The nomogram includes eight parameters, it is simple to use and useful for postoperative risk stratification [5]. This approach, although not yet validated, represents have better predictive performance in hip and knee arthroplasty in comparison to the SAS [5] which a 10-point Surgical Apgar Score (SAS) was recently developed and validated in general and vascular surgery [6, 7].

The purpose of this study is to assess the performance of the arthro-MAP nomogram in predicting predict major complications after Hip and Knee Arthroplasty in the Chinese population.

# Methods

Patients

A retrospective review of all patients underwent Hip and Knee Arthroplasty surgery from March 1, 2017 to August 31, 2019 at the Affiliated Hospital of Guangdong Medical University China. Only patients with complete information available for the nomogram were included.

Research methods

For each patient, prognostic factors incorporated in the arthro-MAP nomogram were extracted and entered into the nomogram calculator to generate a predicted probability of major complications after Hip and Knee Arthroplasty. These factors included lowest intraoperative HR, EBL, preoperative BUN, procedure type (primary, partial and revision), race (non-white, white), ASA score ( < = 2, > 2), comorbidities (0,1, 2, 3), presence of fracture (yes or no).

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 [8].

# Statistical analysis

All statistical analyses were performed using the STATA14.0 statistical software package. Receiver operator characteristics curves (ROC) were produced to evaluate the area under the curve (AUC) and the diagnostic performance of the arthro-MAP nomogram as a predictor of major complications after Hip and Knee Arthroplasty. The AUC (Area under curve) can evaluate the nomogram model discrimination

degree. AUC > 0.6: may make sence; AUC > 0.7: Not bad; AUC > 0.8: Excellent. Nomogram performance was also assessed by DCA and calibration.

# Results

Patient Characteristics

Overall, 414 patients were enrolled. Patient's characteristics are shown on Table 1. 47 patients (11.35%) presented a major complications after Hip and Knee Arthroplasty. The median age of 70.57 ± 12.97 years. 58.2% are male, 41.8% are female. 144 patients with Cardiovascular comorbidities (34.8%); 40 patients with Pulmonary comorbidities (9.7%); 66 patients with Diabetes mellitus. 204 (49.3%) patients with a ASA class=Ⅱ, 196 (47.3%) patients with a ASA class = III and 14(3.4%) patients with a ASA class = IV. Procedure type classification showed a predominance of Primary total hip arthroplasty(49%), over diffuse Primary total knee arthroplasty(27.8%), followed by Hemiarthroplasty(23.2%).

Table 1
Patients characteristics overall and outcomes.

| Patient Characteristics | Overall (N = 414) | No Major Complications (N = 367) | Major Complications (N = 47) | P Value |
|---|---|---|---|---|
| Age(y)[a] | 70.57 ± 12.97 | 69.21 ± 12.44 | 81.21 ± 12.17 | 0.000 |
| Gender (%)[b] | 241(58.2) | 214(51.7) | 27(57.4) | 0.910 |
| Male | 173(41.8) | 153(41.7) | 20(42.6) | 0.005 |
| Female | 144(34.8) | 119(32.4) | 25(53.2) | 0.019 |
| Cardiovascular comorbidity (%)[b] | 40(9.7) | 31(8.4) | 9(19.1) | 0.138 |
| Pulmonary comorbidity(%)[b] | 66(15.9) | 55(14.9) | 11(23.4) | 0.000 |
| Diabetes mellitus(%)[b] | 204(49.3) | 198(53.9) | 6(12.8) | 0.000 |
| ASA Class(%)[b] | 196(47.3) | 161((43.9) | 35(74.4) | 0.555 |
| | 14(3.4) | 8(2.2) | 6(12.8) | 0.001 |
| III | 115(27.8) | 111((30.2) | 4(8.5) | |
| IV | 203(49) | 188((51.2) | 15(31.9) | |
| Procedures(%)[b] | 96(23.2) | 68(18.6) | 28(59.6) | |
| Primary total knee arthroplasty | 270.61(0 ~ 1500) | 205.78(0 ~ 1500) | 216.50(50 ~ 1000) | |
| Primary total hip arthroplasty | 60.25 ± 11.23 | 59.39 ± 10.64 | 66.89 ± 13.38 | |
| Hemiarthroplasty | | | | |
| Estimated blood loss(ml)[c] | | | | |
| Lowest heart rate(bpm)[a] | | | | |

Results are presented as number (percentage) of patients, or as mean ± 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).

Nomogram Validation

The arthro-MAP nomogram ROC curve analysis showed an AUC of 0.816(95%CI: 0.757–0.875) (Fig. 2), indicating that the arthro-MAP nomogram model has a good bootstrap-corrected concordance in the

Chinese population.

Calibration in Hosmer-Lemeshow goodness-of-fit test $x^2 = 17.13$, P = 0.0715(Fig. 3), shows that the arthro-MAP nomogram with predicted outcome rates closely reflecting the observed rates in the Chinese population.

The arthro-MAP nomogram also have a good Decision curve analysis in the Chinese population (Fig. 4). It can help the physicians make clinical efficacy analysis based on clinical practice.

# Discussion

The demand for total knee arthroplasty (TKA) and total hip arthroplasty (THA) is growing rapidly. While this is generally considered to be a safe procedure [9], the exponential growth in the number of procedures invites a greater potential for post-surgical complications, such as surgical site infections, sepsis, joint dislocations, and revision arthroplasties. These complications increase hospital length of stay (LOS) and rates of readmission, and thereby have profound medical and financial ramifications for patients and hospital systems [10]. Therefore some risk prediction models have integrated intraoperative variables to predict postoperative complications[5, 11, 12], in order to provide important information for optimizing postoperative and intraoperative management and improve patient safety by minimizing postoperative complications.

The arthro-MAP nomogram has been shown to predict major postoperative complications in hip and knee arthroplasty based on preoperative and intraoperative variables, with predictive ability superior to that of the Surgical Apgar Score (SAS) [5]. The purpose of our study was to compare nomogram performance at the Chinese population assessed by discrimination and calibration. We show the arthro-MAP nomogram predicted Chinese groups with an AUC of 0.816 and good calibration in Hosmer-Lemeshow goodness-of-fit test $x^2 = 17.13$, P = 0.0715. Our results suggest that the use of the arthro-MAP nomogram in the Chinese population, can help the physicians make clinical efficacy analysis based on clinical practice, apply to Chinese population.

China is the most populated country in the world, and now has the second-largest economy

in the world [13]. The living standards and health system continue to improve, the demand for healthcare, including hip arthroplasty, is increasing [14]. However there are have not a good risk prediction tool has been developed in an attempt to quantify the patient-specific assessment of risk by Chinese. Numerous clinical tools have been developed to predict a variety of TJA patient outcomes, include “scoring systems, nomograms and algorithms” [15]. The nomogram model is the most effective that can realize the individualized prediction of the risk of adverse clinical events by quantifying, graphing, and visualizing the logistic regression results [16].Another reason we decided to choose the arthro-MAP nomogram to validated is because the 8 preoperative and intraoperative variables (lowest HR, EBL, blood urea nitrogen, procedure type, race, ASA score, comorbidities, and presence of fracture) can be easily get form our hospital and be generalizable widely.

We have to acknowledge some limitations to our study. The arthro-MAP nomogram was externally validated using a retrospective data set from a single Chinese institute. For the generalized use of the arthro-MAP nomogram for Chinese patients, validation by other Chinese cohorts is required. Moreover, several variables in the nomogram such as: race and procedure type, are difficult to make a precise assessment preoperatively. Chinese population are all non-white race. We just have three procedure types like Primary total knee arthroplasty, Primary total hip arthroplasty and Hemiarthroplasty, not including Revision total knee arthroplasty, Primary unicondylar knee arthroplasty and Revision total hip arthroplasty. Thus the best way is to build a predictive model using Chinese data.

# Conclusions

Our study validates the arthro-MAP nomogram in Chinese patients with hip and knee arthroplasty. In our experience the arthro-MAP nomogram presented a high accuracy for the major complications in hip and knee arthroplasty. It is an excellent tool to be used by the Chinese physicians.

# Abbreviations

HR: Heart rate; ROC: Receiver operating characteristic curve; AUC: Area under curve; ASA: American Society of Anesthesiologists; BUN: blood urea nitrogen; THA: Total hip arthroplasty; TKA: total knee arthroplasty; EBL: Estimated blood loss; NSQIP: National Surgical Quality Improvement Program; LOS: hospital length of stay

# 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.

### Funding

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.

### Acknowledgements

We thank Dr. JY W of the Affiliated Hospital of Guangdong Medical University Department of Scientific Research for his excellent assistance in the data analysis.

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# Figures

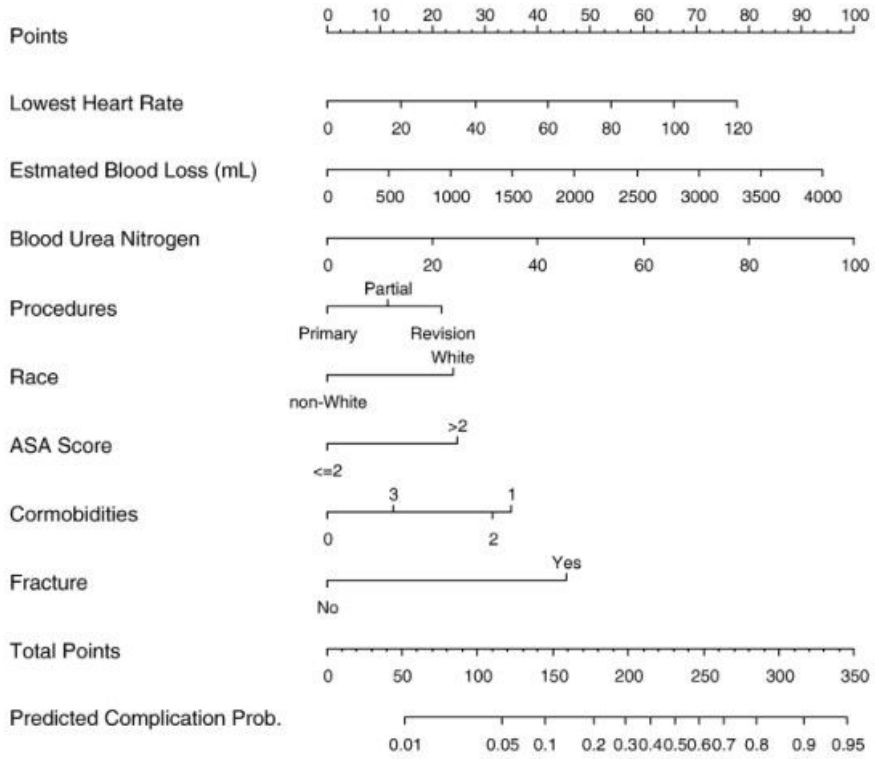


**Fig. 1.** Nomogram – The Morbidity and Mortality Acute Predictor (arthro-MAP). The nomogram computes the probability of having a major postoperative complication. In order to compute the predicted complication probability, a vertical line is to be drawn from the values of the individual variables to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

## Figure 1

Arthro-MAP Nomogram to predict major complications after Hip and Knee Arthroplasty.

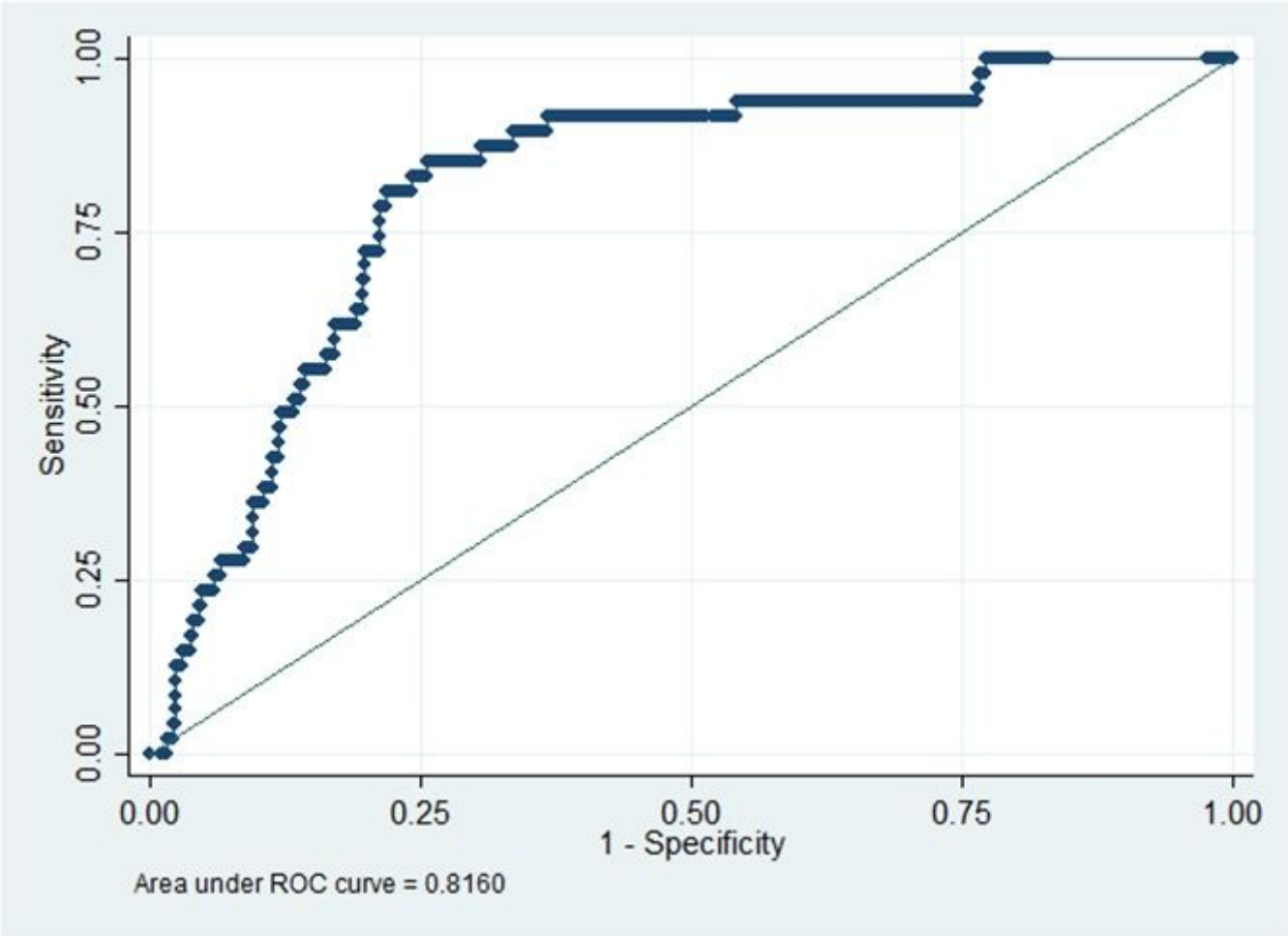


**Figure 2**

ROC curve for the prediction of major complications of the Arthro-MAP nomogram

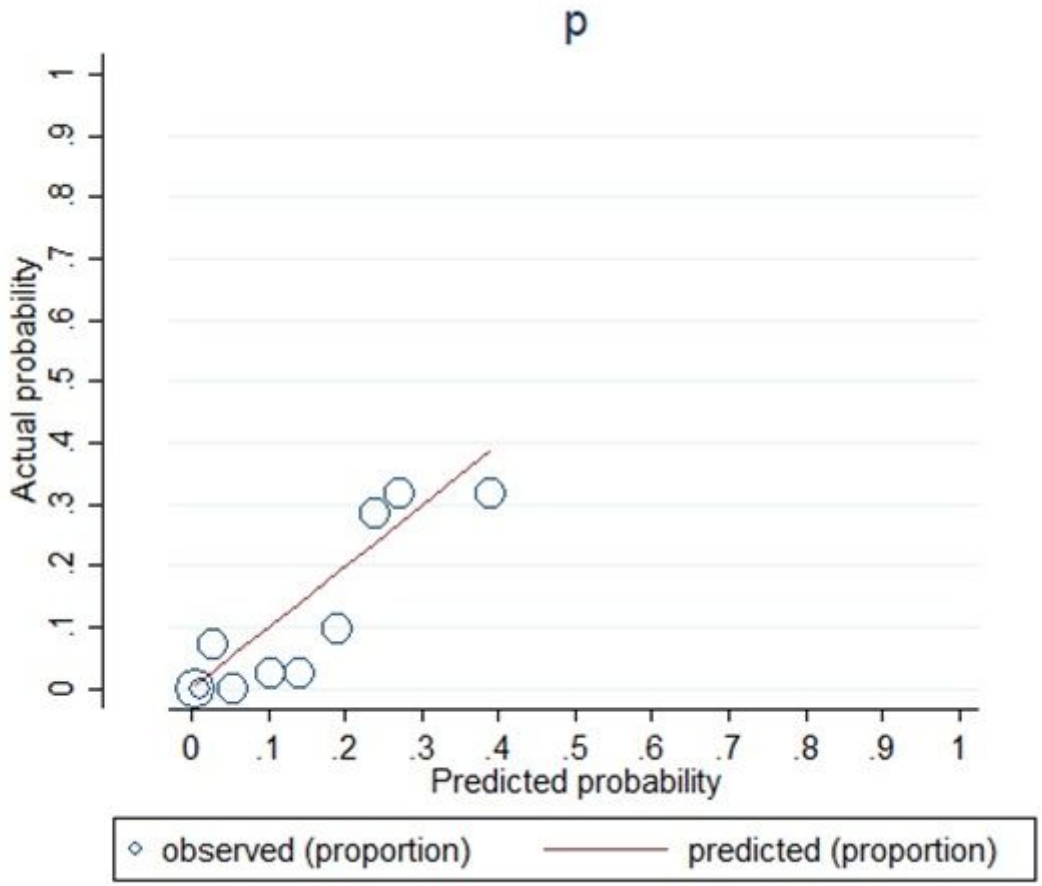


**Figure 3**

Hosmer -Lemeshow test for Arthro-MAP Nomogram to predict major complications after Hip and Knee Arthroplasty.

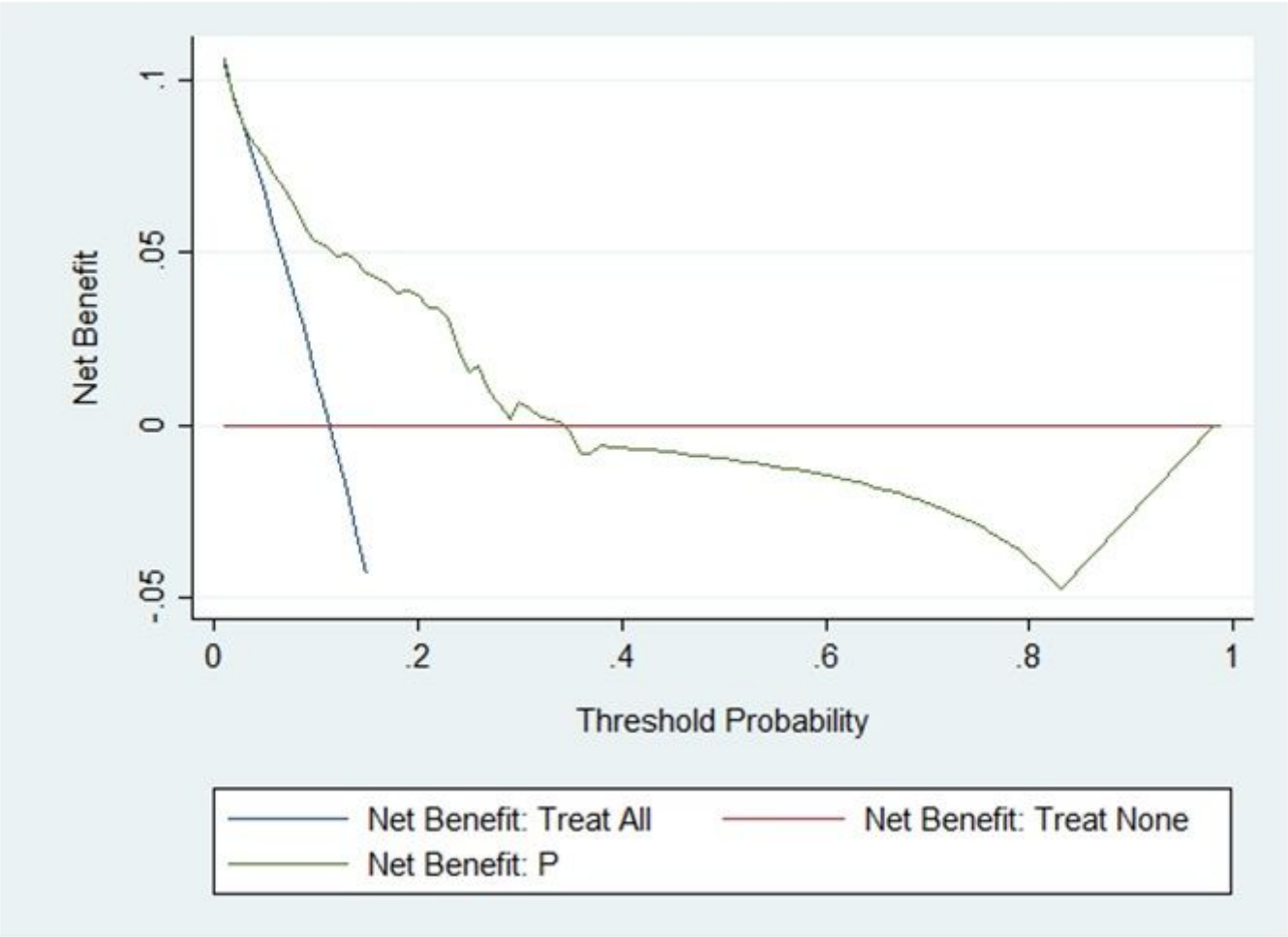


**Figure 4**

Decision curve for Arthro-MAP Nomogram to predict major complications after Hip and Knee Arthroplasty. Solid line: Prediction model. Dotted line: assume all patients have major complications. Thin line: assume no patients have major complications. The graph gives the expected net benefit per patient relative to no Hip and Knee Arthroplasty surgery in any patient (“treat none”).