ORIGINAL ARTICLE

The Use of a Nomogram to Visually Interpret a Logistic Regression Prediction Model for Giant Cell Arteritis

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ABSTRACT

Objective: To illustrate the utility of a nomogram for the prediction of giant cell arteritis (GCA).
Method: A nomogram was constructed from a multivariable logistic regression prediction model with 10 covariates: age, sex, clinical temporal artery abnormality, new-onset headache, jaw claudication, vision loss, diplopia, erythrocyte sedimentation rate, C-reactive protein, and platelet level.

Results: The magnitude and location of the nomogram scale for each predictor variable graphically illustrates the net effect of each covariate and is especially useful for continuous variables such as age and bloodwork values.

Conclusions: Nomograms allow integration and synthesis of the relative importance of clinical variables and provide a graphic representation of the odds ratios, *p* values, and confidence intervals of logistic regression prediction models. Although nomograms and prediction rules cannot substitute for clinical judgment, they help objectify and optimize the individualized risk assessments for patients with suspected GCA.

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A nomogram is a chart or graph of scaled variables that facilitates the approximate computation of a mathematical function via intersecting lines. Nomograms allow the graphical interpretation of numeric statistics. Its etymology is from the Greek “nomos” meaning “law,” and “gramme” meaning “line.”

The first medical nomogram is thought to be from 1928 when L. J. Henderson analysed blood as a physical–chemical substance.¹ Nomograms in ophthalmology and neurology have been used for conditions as diverse as the correlation of Snellen acuity and Titmus stereoacuity,² prognostication of early relapse for demyelinating events,³ prognostication of metastatic uveal melanoma,⁴ and refractive surgery with femtosecond laser.⁵ However, nomograms have not been well described for one of the most vexing of neuro-ophthalmic problems – prognosticating the risk of giant cell arteritis (GCA) prior to temporal artery biopsy.

An individual physician’s “clinical intuition” is often an implicit gestalt judgement that can be imprecise¹⁶. Mathematical prediction models such as logistic regression, proportional hazards

regression, or Markov decision process⁶ provide a more explicit objective decision tool for patient management, but the net effect of multiple variables expressed as odds ratios (ORs), hazard ratios, *p* values, or confidence intervals may be difficult for the average clinician to synthesize. Without an output calculator, multivariable regression formulas can be laborious. Nomograms can provide a graphic understanding of clinical prediction rules and a quick approximation of the output probability.

Numerous prediction algorithms for GCA exist,^{7–13} but despite accompanying calculators,⁹ it may be difficult for clinicians to “fully integrate the predictive diagnostic information” from multivariable prediction models, especially when they are continuous variables such as with erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), or platelets.¹³ In this discussion, we use a TRIPOD-compliant, validated logistic regression prediction model for biopsy-proven GCA as an example.⁷ This logistic regression model has 10 predictor variables: age, sex, new-onset headache, clinical temporal artery abnormality (tenderness

and/or poor pulse), jaw claudication, ischemic vision loss (ischemic optic neuropathy or central retinal artery occlusion or visual pathway stroke), diplopia, the natural logarithm of the ESR, the natural logarithm of the CRP divided by its upper limit of normal, and platelet values.

Nomograms can be generated from commonly available statistical programs such as Stata 14.2 (StataCorp LLC, College Station, TX, USA) to complement logistic regression or Cox hazard regression formulas.¹⁴ The Kattan-style nomogram in Figure 1 is the graphical representation of the logistic regression formula in Table 1.⁷ The location and length of each nomogram line illustrates its relative importance with respect to the risk of GCA. A vertical line drawn from the scale value of each predictor down to the “Score” scale provides the numerical score for that predictor. The sum of the 10 predictors yields the “Total Score” which can be scaled to the final output probability of GCA. An online calculator is available for readers that prefer not to hand tabulate the 10 variables in the nomogram. http://edseling.com/gca_logistic_regression_prediction_rule/

In the nomogram, note that the ESR and CRP are on a log scale. Advanced age and marked

thrombocytosis had the greatest potential to augment the risk score, followed by marked elevation in the CRP and ESR values, jaw claudication, and vision loss. Clinical temporal artery abnormality and new-onset headache had a modest contribution to the risk of GCA. Gender and diplopia were not useful discriminators in this study.

From the logistic regression shown in Table 1, one might wrongly conclude that platelets with OR 1.005 and age (OR 1.046) would not contribute much to the final risk score compared to jaw claudication (OR 3.656) and vision loss (OR 2.803). However, in this logistic regression, jaw claudication and vision loss are binary variables, whereas platelets and age are continuous variables with a wide range. The nomogram provides a “visual perspective of the effect of continuous variables against measured end points.”¹⁵ Although a 1 unit change in the platelet value only changes the OR marginally, a 10-unit increase in platelets has the effect of $e^{(\beta^{\text{platelets}} \times 10)} = e^{(0.0050691 \times 10)} = 1.05 \times$ increase in the OR. A 50-unit increase in platelets results in a $e^{(0.005691 \times 50)} = 1.29 \times$ increase in the odds.

Figure 1. Nomogram of logistic regression model for giant cell arteritis.

ESR = erythrocyte sedimentation rate

CRP_divide_by_ULN = C-reactive protein divided by its upper limit of normal

TA_tender_noPulse = Clinical temporal artery abnormality (tenderness and/or decreased or absent pulse)

New-Headache = new-onset headache

Table 1. Multivariable logistic regression prediction model for biopsy-proven giant cell arteritis⁹ ($n = 530$, Pseudo- $R^2 = 0.2561$, AUROC = 0.820, $p_{\text{Hosmer-Lemeshow}} = 0.549$).

Predictor	Odds ratio	p value	[95% confidence interval]
Age	1.046	0.001	[1.019-1.073]
Female sex	0.859	0.559	[0.515-1.432]
New Headache	1.260	0.426	[0.714-2.221]
TA: tender, no pulse	1.428	0.172	[0.856-2.382]
Jaw Claudication	3.656	<0.001	[2.181-6.129]
Log(CRP/ULN)	1.337	0.003	[1.103-1.620]
Log ESR	1.206	0.273	[0.863-1.684]
Platelets	1.005	<0.001	[1.003-1.007]
Vision Loss	2.803	<0.001	[1.617-4.860]
Diplopia	0.795	0.648	[0.297-2.127]
_cons	0.0003		

TA = temporal artery.

Log = natural logarithm.

CRP/ULN = C-reactive protein divided by its upper limit of normal.

ESR = Westergren erythrocyte sedimentation rate.

Vision loss = ischemic optic neuropathy, central retinal artery occlusion, or other presumed ischemic vision loss.

_cons = constant.

In summary, nomograms of multivariable prediction models allow us to better conceptualize the relative statistical importance of clinical variables and provide a simple graphic representation of the ORs, hazard ratios, p values and confidence intervals of clinical prediction rules. Although nomograms and prediction algorithms cannot substitute for clinical judgment, they can objectify and optimize individualized risk assessments for our neuro-ophthalmic patients.

Disclosure statement

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