Modelling of Mean Arterial Pressure Affected by Stress Score Using Nonparametric Regression Approach Based on Least Squares Spline Estimator

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Abstract. Mean arterialpressure(MAP) is a calculation of the average arterial blood pressure needed for blood circulation to the brain. Blood circulation to the brain carries the supply of food and oxygen the brain needs for nutrition and brain activity. MAP should not be lacking because it can cause diseases such as tachycardi heart rate and hypotension. Likewise, MAP should not be high because it can cause brain blood vessel rupture and hypertension. Stress is believed to have a relationship with hypertension. This is thought to be through sympathetic nerve activity which can increase blood pressure intermittently. Besides that, it can also stimulate the kidneys of the kidneys to release the hormone adrenaline and stimulate the heart to beat faster and stronger, so that blood pressure will increase. An increase in stress scores can be followed by an increase in MAP as well, therefore it is necessary to study the effect of changes in the stress scores on MAP in efforts to prevent hypertension. To investigate that, in this study, we use two approaches, i.e., parametric regression approach and nonparametricregression approach based on the least square spline estimator that can accommodate changes in data patterns. The results show that for both the parametric regression approach and the nonparametric regression approach give mean square error of 42 and 33.92, respectively. It means that nonparametric regression approach based on least square spline estimator is better than the parametric regression approach.

Keywords: *Mean Arterial Pressure; Stress; Least-Square Spline Estimator*

1. INTRODUCTION

Mean Arterial Pressure (MAP) is the average arterial blood pressure during a single heartbeat cycle obtained from systole and diastole blood pressure measurements. According to [1] MAP is the weighted average time for arterial pressure throughout the heart cycle, which is calculated as diastolic pressure plus one third of the pulse pressure. Perfusion of vital organs requires maintenance of a minimum MAP of 60 mmHg. If the MAP falls below this point for a long time, manifestations of end organs such as ischemia and infarction can occur. If MAP drops significantly, blood will not be able to penetrate brain tissue, there will be loss of consciousness, and nerve death will occur quickly[2]. The body has several protective mechanisms to regulate MAP and ensure adequate perfusion levels are maintained for the functioning of all organs.

The results of MAP measurements are determined by blood pressure measurements. Blood pressure measurement results do not show constant results at all times. Although in good condition though. The blood pressure results must change at any time. The inconstant results of blood pressure measurements are influenced by various factors, namely age, sex, stress, race, medication, arterial elasticity, cardiac output, peripheral vascular pressure, blood volume, and blood viscosity[3].

Besides internal factors there are factors outside the body that can affect blood pressure in humans, namely psychological factors and one of them is stress. Stress that occurs in the community will trigger an increase in blood pressure with a mechanism that triggers an increase in adrenaline levels. Stress will stimulate the sympathetic nerves will increase blood pressure and increased cardiac output. Stress will increase if the resistance of peripheral

blood vessels and cardiac output increases, which stimulates sympathetic nerves. So that stress will react to the body which include increasing muscle tension, increasing heart rate and increasing pressure. blood. This reaction is raised when the body reacts quickly which is not used, it can trigger the occurrence of diseases including hypertension. [4] With the influence of stress on the value of MAP, it needs to be modelled its authorship. Until now there has been no research on the effect of stress levels on the value of MAP.

To make estimation model the method used in statistics is regression. There are two approaches in regression, namely parametric regression and nonparametric regression. In nonparametric regression there are many estimators to estimate functions, namely kernel, local linear, local polynomial and spline estimator. Researchers who have studied nonparametric regression models by using local polynomials [5], kernels [6], local linear [7], and spline estimators [8-15]. Changes in stress levels are followed by changes in MAP values. Stress levels at different levels cannot be confused with the MAP value so it needs to be estimated locally by using the least square spline estimator. Spline estimators can provide high flexibility to accommodate changes in data behaviour locally because in the spline there are knots that are combined with points of behaviour change.

2. METHODS

2.1. Least Square Spline in Nonparametric Regression

spline is one of the estimators of nonparametric regression. spline estimator has the ability to estimate the behaviour of data that tends to differ at different intervals. The different intervals are joint fusion points where a pattern of behaviour changes from a function at different intervals[11]. In general, the function f in spline space has the order p with points knots $K_1, K_2, \dots, K_m$ is any function that can be expressed as the following equation:

$$g(x_i) = \sum_{j=0}^{p} \beta_j x^j + \sum_{j=1}^{m} \beta_{j+p} \left(x - K_j\right)_+^p \quad (1)$$

where, $\left(x - K_{j-p}\right)_+^p = \begin{cases} \left(x - K_{j-p}\right)^p, x \geq K_{j-p} \\ 0 \qquad\qquad , x < K_{j-p} \end{cases}$

If given $\lambda = (K_1, K_2, \dots, K_m)$ and β are the parameters of the model with p is the order of spline. The β parameter can be calculated by the following equation

$$\hat{\beta} = \left(X_\lambda{}^T X_\lambda\right)^{-1} X_\lambda{}^T y \quad (2)$$

Estimator of $g(x_i)$ in (1) can be expressed as

$$\hat{g}_\lambda(x) = H(\lambda) y \quad (3)$$

where $H(\lambda) = X_\lambda (X_\lambda^T X_\lambda)^{-1} X_\lambda^T$.

2.2. Generalized Cross Validation

In nonparametric regression one of the criteria for determining the optimum knot point is the Generalized Cross Validation (GCV) method. The best least square spline estimator is obtained based on the minimum GCV value. The GCV function for nonparametric spline regression model is:

$$GCV(K_1, K_2, \dots, K_m) = \frac{MSE(K_1, K_2, \dots, K_m)}{(n^{-1} tr[I - H(K_1, K_2, \dots, K_m)])^2} \quad (4)$$

where $MSE(K_1, K_2, \dots, K_m) = n^{-1} \sum_{i=1}^{n} (y_i - \hat{g}(x_i))^2 \quad (5)$

The optimal knots point is obtained by the minimum GCV value.

3. DATA AND STEPS OF ANALYZE

The data used in this study are primary data obtained from interviews with questionnaires on Poli Cardiac at the Haji Hospital in Surabaya conducted from April to May 2019 with 39 respondents. The variables used for this study consisted of response variables and predictor variables. The response variable (Y) is Mean Arterial Pressure, while the predictor variable used is the stress score (x). The steps to model using the nonparametric least square spline estimator regression approach as follows:

a. Input data in pairs for response variable (*y*), i.e., Mean Arterial Pressure (MAP) and predictor variable (*x*), i.e., stress score.
b. Determine optimum of the number of knots, knots, and the order based on minimum GCV value in (4)
c. Estimate parameters by using least square spline estimator in (3)
d. Determine goodness of fit criterion for MSE (in 5)
e. Plot observed and the estimatedof Mean Arterial Pressure (MAP) versus stress score.
f. Interpret the estimated model of Mean Arterial Pressure (MAP) of stress score.

4. RESULTS AND DISCUSSION

For estimating the Mean Arterial Pressure (MAP) based on stress score we need to make a scatter plot to find out where there is a change in the behavior of the data in figure 1 as follows:

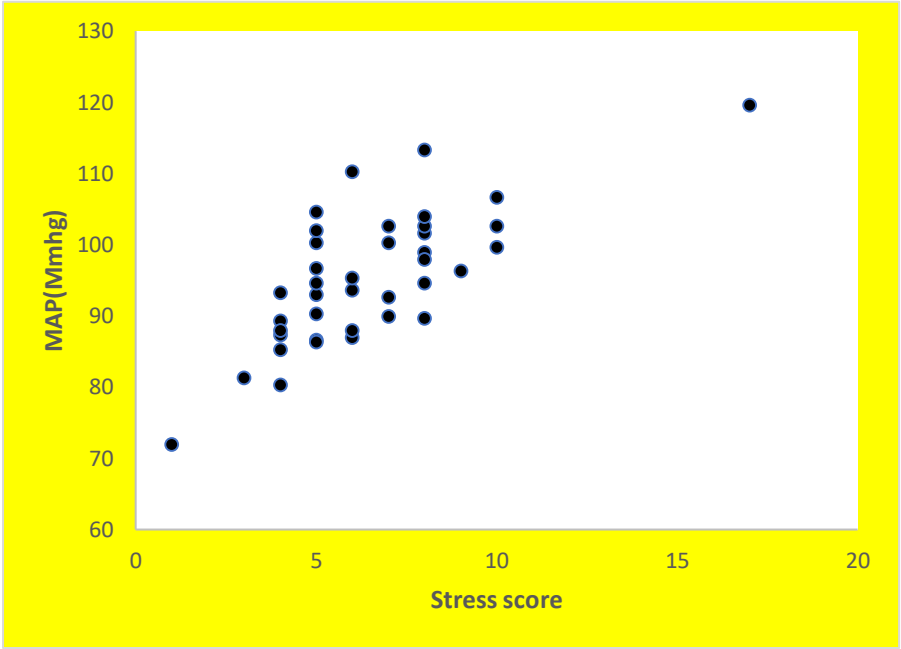

Figure 1. Scatter plot of MAP versus stress score

Based on **Figure 1.** it can be seen that the data ploting does not form a specific pattern and there is a change in behavior in the MAP data pattern on the stress score so that using the nonparametric regression approach estimator least square spline is very suitable for estimating the model because it is in the form of fragments of function segments combined with knots. The knots in this study were obtained using the quantile method and compressed the results in table 1 as follows:

Table 1. Number of knots, knots, order,and GCV values

Number of Knots	Knots	Order	GCV Values
1	6	1	42.75
		2	43.71
2	5; 7.3	1	42.12
		2	46.2
3	5; 6 ; 8	1	44.44
		2	48.04

Based on **Table 1,**the results obtained with the smallest GCV criteria is 42.12 with the number of knots 2, with knots 5 and 7.3 and order 1 .Base on the result we obtain the MSE value is 33.92. And estimation models with non parametricapproach can be formed as follows:

$$\hat{y} = 64.22 + 5.99x - 4.52(x - 5) + 0.75(x - 7.3)$$

$$\hat{y} = \begin{cases} 64.22 + 5.99x & , \text{ for } x < 5 \\ 86.82 + 1.47x, & \text{for } 5 \leq x < 7.3 \\ 81.35 + 2.22x & , \text{ for } x \geq 7.3 \end{cases}$$

Furthermore, based on the estimated model obtained, it can be made an estimation plot and observation of Mean Arterial Pressure (MAP) with the stress score in figure 2 as follows:

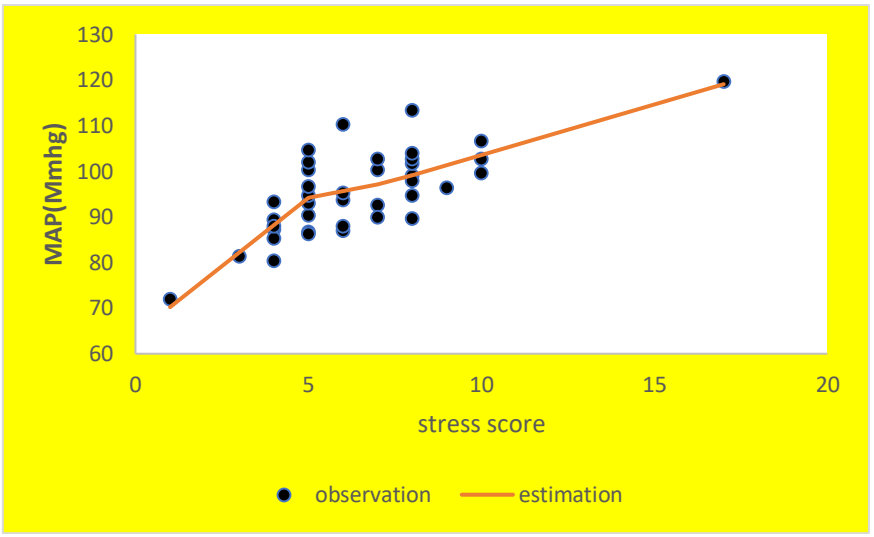

Figure 2. Plots ofobservation and estimated MAP versus stress score using nonparametric approach

Based on the model obtained, if the stress score is less than 5, each increase in 1 unit of stress score can increase the MAP by 5.99. If the stress score is more than or equal to 5 and less than 7.3, each 1 unit increase in stress score can increase the MAP by 1.47. if the stress score is more than 7.3, then every 1 unit increase in stress score can increase the MAP by 2.22.

Next we estimate the models with parametric approach and we obtain the models as follows :

$$\hat{y} = 78.8 + 2.58x$$

Based on the model obtained, each increase in 1 unit of stress score can increase the MAP by 2.58 .The MSE value from the model is 42. And we showscater plot observation and estimation of MAP base on stress score in figure 3 as follows:

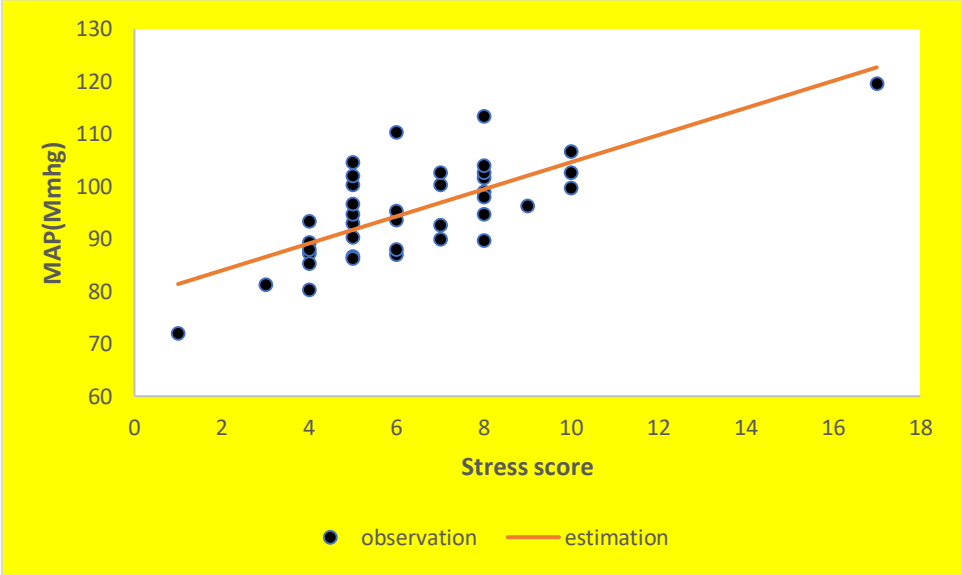

Figure 3. Plotsof observation and estimated MAP versus stress score using parametric approach

Based on the results obtained from the parametric regression approach and the non-parametric regression approach it is proven that with the non-parametric regression approach it is better to estimate the Mean Arterial Pressure (MAP) based on the stress score seen from the smaller MSE value.

5. CONCLUSIONS

The effects of stress score on Mean Arterial Pressure (MAP) have different patterns at some investigated interval of levels of stress scores, so that the use of nonparametric regression approach based on least square estimator is more appropriate than that of parametric regression approach based on linear model.

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