# A Clinical Risk Score for Predicting Paraspinal Extramedullary Hematopoiesis in Patients with Thalassemia: The KKU-EMH Score

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***Background:*** *Paraspinal extramedullary hematopoiesis (EMH) is uncommon, but it is one of major complications of increased morbidity in patients with thalassemia.*
***Objective:*** *To develop a clinical risk score for predicting paraspinal extramedullary hematopoiesis in patients with thalassemia.*
***Material and Method:*** *A retrospective study was conducted in adult patients with thalassemia at Srinagarind Hospital, Khon Kaen University (KKU) and Udonthani Hospital, Thailand. Paraspinal EMH was defined as radiologic evidence of EMH foci with or without symptoms. The clinical parameters significantly associated with EMH were entered into the logistic regression model. The risk score was derived from the final model's coefficients. A receiver-operating characteristic (ROC) curve was constructed to determine the area under the ROC curve and the cut-off point.*
***Results:*** *The KKU-EMH score included: 1) age greater than 25 year (2 points) and 2) thalassemic facie (3 points). Using the cut-off of 5 points, the score showed good discrimination with an area under the ROC curve of 0.83 (95% CI 0.76 to 0.90).*
***Conclusion:*** *Advanced age and thalassemic facie are independent risk factors for paraspinal EMH in patients with thalassemia. The KKU-EMH score is a practical score. It can be used as a screening tool for paraspinal EMH in patients with β-thalassemia.*

***Keywords:*** *Paraspinal extramedullary hematopoiesis, Risk score, Thalassemia*

***J Med Assoc Thai 2017; 100 (4): 389-95***
***Full text. e-Journal:*** *http://www.jmatonline.com*

Thalassemia syndrome is an inherited hemoglobin disorder resulting from impaired synthesis of the α-globin or β-globin chains. Thalassemia syndrome can be divided into three main groups according to the variety of thalassemia phenotypes including, 1) thalassemia major, 2) thalassemia intermedia, and 3) thalassemia minor. Recently the terms of transfusion-dependent thalassemia (TDT) and non-transfusion-dependent thalassemia (NTDT) have been used in the patients with thalassemia major and the patients with thalassemia intermedia[1].

Extramedullary hematopoiesis (EMH) is one of the major thalassemia-related complications. Ineffective erythropoiesis is believed to be the main mechanism which promotes the development of EMH. Previous studies reported the incidence of EMH that varied from 10% to 27% in thalassemia major[2,3] and 11% to 20% in thalassemia intermedia[2,4]. Extramedullary hematopoiesis can be found in various sites of the body including: lymph nodes, pleura, retroperitoneal tissue, brain, peripheral and cranial nerves, kidney, adrenal gland, and the spinal cord[5-10].

Paraspinal EMH is the EMH foci around the spinal cord. It is one of the most important sites of EMH because it may lead to long-term morbidity and mortality.

Literature has shown various clinical risk factors for EMH, e.g., inadequate transfusion therapy, advanced age, inadequate chelation, and iron overload[2,11,12]. The present study was aimed to determine clinical risk factors and develop a clinical

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risk score for predicting paraspinal EMH in patients with thalassemia.

## Material and Method

A retrospective study was conducted in patients with thalassemia from the thalassemia registry entitled "Epidemiologic Study of major complications in Adult and Adolescent patients with thalassemia in Northeastern Thailand" (E-SAAN study), at Srinagarind University Hospital and Udonthani Hospital. Eligible participants were patients aged 18 years old or older with a diagnosis of thalassemia according to their genotype data. Clinical characteristics and laboratory data that literature indicated as risk factors for EMH were collected.

### *Diagnosis of paraspinal extramedullary hematopoiesis*

Paraspinal EMH was defined as the presence of clinical symptoms of paraspinal EMH or evidence of EMH by ultrasonography, computed tomography scan (CT scan) or magnetic resonance imaging (MRI).

### *Thalassemic facies*

Thalassemic facies is defined as the presence of one of the following findings included, 1) bossing of the skull, 2) a prominent malar eminence, 3) depression of the bridge of the nose, and 4) hypertrophy of the maxillae, which tends to expose the upper teeth. Thalassemic facies were evaluated by one doctor to prevent bias.

The research protocol was approved by both the Ethics Review Board of the Faculty of Medicine, Khon Kaen University, and Udonthani Hospital.

### *Statistical analysis*

Categorical parameters were reported as numbers and percentages. Continuous parameters were reported as means and standard deviations (SD). The sample size was calculated according to the formula for the logistic regression analysis, which has been proposed by Hsieh et al[13] with 80% power at a 0.05 significance level. All clinical risk factors were evaluated by using univariate and multivariate logistic regression to determine the potential for prediction of paraspinal EMH. Backward stepwise multivariable logistic regression was applied to obtain the final model. The clinical risk score was derived from the logistic regression model. The clinical risk score was weighted by coefficients of individual factors in the predictive model. The coefficients of clinical factors were rounded to the nearest number to simplify the risk score. The receiver-operating characteristics (ROC) curve was constructed to determine the area under the ROC curve and the optimal cut-off point. The 2x2 table was constructed to determine the sensitivity and specificity of the risk score. All statistical analyses were performed using STATA statistical software version 10 (StataCorp, College Station, TX). A *p*-value of less than 0.05 was considered statistically significant.

## Results

The records of 274 patients were reviewed. Paraspinal EMH was found in 15 patients (5.5%). Baseline clinical characteristics data of all patients were shown in Table 1. The mean age was 30$\pm$13 years. The mean ages at first diagnosis and at first blood transfusion were 10.8$\pm$14.2 years and 12.5$\pm$14.7 years. Splenectomy was found in 97 patients (35.5%) with the mean time after splenectomy of 4.6$\pm$7.9 years. Most of the patients previously received blood transfusions (95.2%). Iron chelation therapy was given to 200 patients (73%). Thalassemic facies were noted in 119 patients (43.4%).

Clinical characteristics of 15 patients with paraspinal EMH were shown in Table 2. All patients with paraspinal EMH had β-thalassemia. Among 15 patients with β-thalassemia, the codon 41/β42 and Hb E was the most common mutation in these patients (53.3%), followed by the codon β17 and Hb E (26.6%). Most of the patients with paraspinal EMH had undergone splenectomy (60%). Radiotherapy and blood transfusions were the most common treatment modality in these patients (73.3%). One patient with a history of multiple recurrent paraspinal EMH received hydroxyurea.

Univariate analyses of the risk factors for paraspinal EMH in patients with thalassemia were shown in Table 3. There were four clinical risk factors that included, 1) Age older than 25 years, 2) Splenectomy, 3) Time after splenectomy of more than five years, and 4) Thalassemic facies that showed statistical significance for paraspinal EMH.

Multivariate analyses of the clinical risk factors for EMH in patients with thalassemia were shown in Table 4. Age older than 25 years and thalassemia facies remained significantly associated to paraspinal EMH after adjustment for other factors with an adjusted odds ratio (95% CI) and *p*-value of 7.3 (1.5 to 35.7), $p = 0.01$ and 13.8 (1.6 to 115.4), $p = 0.01$.

The logistic regression model was shown in Table 5. The logistic regression model is -6.1+1.7 (age

**Table 1.** Baseline clinical characteristics in 274 patients with thalassemia

| Characteristics | Patients (n = 274) |
|---|---|
| Mean age ±SD, years (at enrollment) | 30±13 |
| Mean age at first diagnosis ±SD, years | 10.8±14.2 |
| Mean age at first blood transfusion ±SD, years | 12.5±14.7 |
| Mean time after splenectomy ±SD, years | 4.6±7.9 |
| Mean hemoglobin ±SD, g/dl | 7.3±1.6 |
| Mean platelet count ±SD, x $10^9$/l | 394.4±265 |
| Mean nucleated RBC/100 WBC ±SD, x $10^6$/l | 128.2±255 |
| Mean serum ferritin ±SD, ng/ml | 1,886±1,920.2 |
| Paraspinal extramedullary hematopoiesis, n (%) | |
| No | 259 (94.5) |
| Yes | 15 (5.5) |
| Gender, n (%) | |
| Female | 170 (62) |
| Male | 104 (38) |
| Splenectomy, n (%) | |
| No | 176 (64.5) |
| Yes | 97 (35.5) |
| Thalassemic facies, n (%) | |
| No | 155 (56.6) |
| Yes | 119 (43.4) |
| Previous blood transfusion, n (%) | |
| No | 13 (4.8) |
| Yes | 261 (95.2) |
| Previous iron chelation, n (%) | |
| No | 74 (27) |
| Yes | 200 (73) |
| Genotype group, n (%) | |
| β-thalassemia/Hb E | 177 (64.5) |
| Homozygous β-thalassemia | 1 (0.4) |
| Hb H disease | 19 (6.8) |
| Hb H disease with Hb CS | 24 (8.7) |
| Hb H disease with Hb Pakse | 4 (1.6) |
| EABart's disease | 13 (4.7) |
| EABart's disease with Hb CS | 30 (10.9) |
| EFBart's disease with Hb CS | 2 (0.8) |
| EABart's disease with Hb Pakse | 2 (0.8) |
| EFBart's disease | 2 (0.8) |

EMH = Extramedullary hematopoiesis, Hb CS = Hemoglobin Constant spring, Hb Pakse = Hemoglobin Pakse

>25 years) + 2.8 (thalassemic facies).

The predictive model was simplified to the clinical risk score as shown in Table 6. The KKU-EMH score for predicting paraspinal EMH included, 1) age older than 25 years (2 points), and 2) thalassemic facies (3 points).

The receiver-operating characteristic (ROC) curve was constructed; the area under the ROC curve was 0.83; 95% CI 0.76 to 0.90 (Fig. 1).

The 2x2 table of the KKU-EMH score was shown in Table 7. Using the cut-off of 5 points, the KKU-EMH score had a sensitivity and specificity of 80% and 77.9% respectively.

## Discussion

Prevalence of paraspinal EMH is lower than the previous studies in patients with thalassemia[3,8] (5.5 % vs. 11% to 27%). The low prevalence of paraspinal EMH in the present study might be explained by three main factors including, 1) the under diagnoses of

**Table 2.** Clinical characteristics in 15 thalassemic patients with paraspinal extramedullary hematopoiesis

| No. | Age/sex | β-gene mutation | Hb (g/dl) | Splenectomy | Investigation | Treatment |
|---|---|---|---|---|---|---|
| 1 | 18/M | Codons 41/42 and Hb E | 6.1 | Yes | MRI scan | Radiotherapy<br>Blood transfusion |
| 2 | 34/F | Codon 17 and Hb E | 6.2 | No | MRI scan | Surgery<br>Blood transfusion |
| 3 | 28/M | Codon 17 and Hb E | 6.1 | Yes | MRI scan | Radiotherapy<br>Blood transfusion<br>Hydroxyurea |
| 4 | 47/F | Codons 41/42 and Hb E | 8.9 | No | MRI scan | Radiotherapy<br>Blood transfusion |
| 5 | 41/F | Codons 71/72 and Hb E | 6.6 | Yes | CT scan | Radiotherapy<br>Blood transfusion |
| 6 | 53/M | Codon 17 and Hb E | 8.0 | Yes | MRI scan | Radiotherapy<br>Blood transfusion |
| 7 | 34/F | Codons 41/42 and Hb E | 8.2 | Yes | MRI scan | Radiotherapy<br>Blood transfusion |
| 8 | 26/M | Codons 41/42 and Hb E | 7.0 | Yes | MRI scan | Radiotherapy<br>Blood transfusion |
| 9 | 33/M | Codons 41/42 and Codons 41/42 | 10 | No | MRI scan | Radiotherapy<br>Blood transfusion |
| 10 | 49/M | Codon 17 and Hb E | 7.3 | No | CT scan | Blood transfusion |
| 11 | 32/F | Codon IVSI#5 and Hb E | 6.6 | Yes | MRI scan | Surgery<br>Blood transfusion |
| 12 | 23/M | Codons 41/42 and Hb E | 7.1 | Yes | MRI scan | Radiotherapy<br>Blood transfusion |
| 13 | 35/F | Codons 41/42 and Hb E | 7.4 | Yes | MRI scan | Radiotherapy<br>Blood transfusion |
| 14 | 54/F | Codons 41/42 and Hb E | 8.1 | No | MRI scan | Radiotherapy<br>Blood transfusion |
| 15 | 45/M | Codons 41/42 and Hb E | 6.8 | Yes | CT scan | Surgery<br>Blood transfusion |

MRI = Magnetic Resonance Imaging; CT scan = Computed tomography

**Table 3.** Univariate analysis of clinical risk factors for paraspinal extramedullary hematopoiesis in 274 patients with thalassemia

| Variables | OR (95% CI) | *p*-value |
|---|---|---|
| Age >25 years | 7.3 (1.6 to 32.9) | 0.010 |
| Male gender | 0.7 (0.2 to 1.9) | 0.470 |
| Splenectomy | 3.9 (1.3 to 11.8) | 0.015 |
| Time after splenectomy >5 years | 4.5 (1.5 to 13.2) | 0.006 |
| Thalassemic facies | 20.5 (2.6 to 158.5) | 0.004 |
| Hemoglobin ≤7 g/dl | 1.3 (0.5 to 3.8) | 0.560 |
| Serum ferritin >1,000 ng/ml | 1.3 (0.2 to 3.1) | 0.620 |
| Age at first diagnosis ≤2 years | 1.4 (0.5 to 4.1) | 0.470 |
| Age at first blood transfusion >15 years | 0.6 (0.1 to 2.2) | 0.450 |

paraspinal EMH because radiologic imaging was not performed in all patients due to not having clinical symptoms, 2) paraspinal EMH was frequently found in the third decade of life, but the majority of patients in

**Table 4.** Multivaritae analysis of clinical risk factors for paraspinal extramedullary hematopoiesis in 274 patients with thalassemia

| Variables | AOR (95% CI) | *p*-value |
|---|---|---|
| Age >25 years | 7.3 (1.5 to 35.7) | 0.01 |
| Hemoglobin ≤7 g/dl | 0.6 (0.2 to 2) | 0.45 |
| Splenectomy | 2.3 (0.2 to 24) | 0.48 |
| Time after splenectomy >5 years | 1.5 (0.1 to 15) | 0.71 |
| Thalassemic facies | 13.8 (1.6 to 115.4) | 0.01 |
| Serum ferritin >1,000 ng/ml | 1.2 (0.3 to 4.2) | 0.73 |

**Table 5.** The logistic regression model

| Variables | Coefficient (95% CI) | *p*-value |
|---|---|---|
| Age >25 years | 1.7 (0.2 to 3.3) | 0.020 |
| Thalassemic facies | 2.8 (0.8 to 4.9) | 0.006 |
| Constant | -6.1 | |

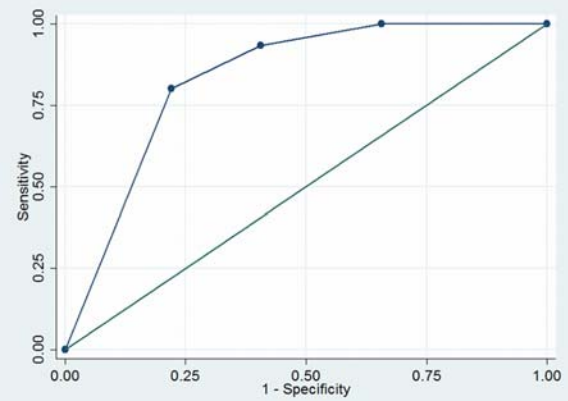
**Table 6.** The KKU-EMH score for predicting paraspinal extramedullary hematopoiesis

| Clinical parameter | Score |
|---|---|
| Age >25 years | 2.0 point |
| Thalassemic facies | 3.0 point |

**Table 7.** The 2x2 table of the KKU-EMH score

| The KKU-EMH score | Paraspinal extramedullary hematopoiesis (EMH) | | Total |
|---|---|---|---|
| | EMH | No EMH | |
| 5 | 12 | 57 | 69 |
| <5 | 3 | 202 | 205 |
| Total | 15 | 259 | 274 |

Sensitivity = 80%, Specificity = 77.9%




Area under ROC curve = 0.83; 95% CI 0.76 to 0.90

**Fig. 1** Receiver-operating characteristics (ROC) curve of the KKU-EMH score.

the present study were younger than 30 years old (172, 62.7%) and 3) the high numbers of patients with α-thalassemia (96, 35%) in the present study's cohort demonstrated that paraspinal EMH is not common in these patients.

Advancing age and thalassemic facies are significant risk factors. The clinical risk score for paraspinal EMH (KKU-EMH score) included 1) age older than 25 years (2 points) and 2) thalassemic facies (3 points). Using the cut-off of 5 points, the score showed a good prediction for paraspinal EMH in patients with thalassemia. The risk score had sensitivity and specificity of 80% and 77.9% respectively.

Age is one of the important risk factors for paraspinal EMH. Previous studies have shown that an increased age was significantly associated with EMH[2,11]. A recent study in Thai patients with thalassemia found that the peak incidence of paraspinal EMH was the third decade of life and afterward[12].

An interesting finding was that all patients with paraspinal EMH had β-thalassemia (14 patients with β-thalassemia/Hb E and 1 patient with homozygous β-thalassemia). None of the patients with α-thalassemia (both deletion and non-deletion α-thalassemia) developed paraspinal EMH. The most common β-gene mutation in patients with paraspinal EMH was codon 41/42 and Hb E followed by codon 17 and Hb E, which are the most common $\beta^0$ mutations in the South East

Asian region. This finding is similar to the previous report by Ricchi P et al. They found that extramedullary hematopoiesis is prevalent in patients with IVS1-6/ codon 39 mutations, which is the common $\beta^0$ mutation in Italy[3].

EMH is a compensatory response to ineffective erythropoiesis in patients with thalassemia. Supporting this, the previous study showed that the high level of the soluble form of transferrin receptor (sTfR), a marker of bone marrow erythropoietic activity, could predict the presence of paraspinal EMH in patients with thalassemia[14]. Thalassemic facies arise from bone expansion due to ineffective erythropoiesis in patients with thalassemia. Therefore, thalassemic facies is a clinical manifestation of ineffective erythropoiesis which can be used as a clinical predictive factor for the developing of EMH.

A limitation of the present study was done as a retrospective study, and the radiologic studies were not performed in all patients.

The KKU-EMH score could have a clinical implication as a screening test for paraspinal EMH in patients with β-thalassemia. Early detection and early treatment of the paraspinal extramedullary hematopoiesis in these patients may reduce the neurological deficits and prevent long-term morbidity. In conclusion, the KKU-EMH score is a simple and practical score with good diagnostic value. Further validation in different clinical settings is needed to determine whether the score can be used in general practices.

**What is already known on this topic?**

Paraspinal extramedullary hematopoiesis (EMH) is one of the major thalassemia-related complications. Ineffective erythropoiesis is believed to be the main mechanism which promotes the development of EMH. Paraspinal EMH is more prevalent in those patients with severe β-gene mutation than other types of thalassemia. Advanced age is known to be one of the important clinical risk factors for paraspinal EMH. To the best of known knowledge, no clinical risk score for predictive paraspinal EMH exists.

**What this study adds?**

This study developed the KKU-EMH score, which is a clinical risk score for predicting paraspinal EMH in patients with thalassemia. The KKU-EMH score consists of 2 important clinical risk factors included: 1) Age >25 years, (2 points) and 2) thalassemic facies, (3 points). Using the cut-off of 5 points, the score showed good discrimination between the low-risk group and the high-risk group for paraspinal EMH in patients with thalassemia.

**Acknowledgements**

The present study received grant support from the National Research Council of Thailand and the Thailand Research Fund (number IRG 5780016). The authors would like to thank Emeritus Professor James A. Will, University of Wisconsin-Madison, for helping in preparing the manuscript.

**Potential conflicts of interest**

None.

**References**

1. Weatherall DJ. The definition and epidemiology of non-transfusion-dependent thalassemia. Blood Rev 2012; 26 (Suppl 1): S3-6.
2. Tantawy AA, Adly AA, Mahdy SA, Kamel GZ. Spinal cord compression and extramedullary hematopoiesis in young Egyptian beta-thalassemia patients. Hemoglobin 2009; 33: 448-62.
3. Ricchi P, Ammirabile M, Spasiano A, Costantini S, Di Matola T, Pepe A, et al. Extramedullary haematopoiesis correlates with genotype and absence of cardiac iron overload in polytransfused adults with thalassaemia. Blood Transfus 2014; 12 (Suppl 1): s124-30.
4. Dore F, Cianciulli P, Rovasio S, Oggiano L, Bonfigli S, Murineddu M, et al. Incidence and clinical study of ectopic erythropoiesis in adult patients with thalassemia intermedia. Ann Ital Med Int 1992; 7: 137-40.
5. Aessopos A, Tassiopoulos S, Farmakis D, Moyssakis I, Kati M, Polonifi K, et al. Extramedullary hematopoiesis-related pleural effusion: the case of beta-thalassemia. Ann Thorac Surg 2006; 81: 2037-43.
6. Keikhaei B, Shirazi AS, Pour MM. Adrenal extramedullary hematopoiesis associated with beta-thalassemia major. Hematol Rep 2012; 4: e7.
7. Ross P, Logan W. Roentgen findings in extramedullary hematopoiesis. Am J Roentgenol Radium Ther Nucl Med 1969; 106: 604-13.
8. Haidar R, Mhaidli H, Taher AT. Paraspinal extramedullary hematopoiesis in patients with thalassemia intermedia. Eur Spine J 2010; 19: 871-8.
9. Intragumtornchai T, Arjhansiri K, Posayachinda

M, Kasantikul V. Obstructive uropathy due to extramedullary haematopoiesis in beta thalassaemia/haemoglobin E. Postgrad Med J 1993; 69: 75-7.
10. Fucharoen S, Suthipongchai S, Poungvarin N, Ladpli S, Sonakul D, Wasi P. Intracranial extramedullary hematopoiesis inducing epilepsy in a patient with beta-thalassemia—hemoglobin E. Arch Intern Med 1985; 145: 739-42.
11. Taher AT, Musallam KM, Karimi M, El Beshlawy A, Belhoul K, Daar S, et al. Overview on practices in thalassemia intermedia management aiming for lowering complication rates across a region of endemicity: the OPTIMAL CARE study. Blood 2010; 115: 1886-92.
12. Teawtrakul N, Chansung K, Sirijerachai C, Wanitpongpun C, Thepsuthammarat K. The impact and disease burden of thalassemia in Thailand: a population-based study in 2010. J Med Assoc Thai 2012; 95 (Suppl 7): S211-6.
13. Hsieh FY, Bloch DA, Larsen MD. A simple method of sample size calculation for linear and logistic regression. Stat Med 1998; 17: 1623-34.
14. Ricchi P, Ammirabile M, Costantini S, Di Matola T, Verna R, Diano A, et al. A useful relationship between the presence of extramedullary erythropoeisis and the level of the soluble form of the transferrin receptor in a large cohort of adult patients with thalassemia intermedia: a prospective study. Ann Hematol 2012; 91: 905-9.

## *คะแนนความเสี่ยงสำหรับพยากรณ์ภาวะการสร้างเม็ดเลือดนอกไขกระดูกข้างไขสันหลังในผู้ป่วยโรคธาลัสซีเมีย: คะแนน KKU-EMH*

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***ภูมิหลัง:*** *การสร้างเม็ดเลือดนอกไขกระดูกข้างไขสันหลังเป็นภาวะที่พบไม่บ่อยแต่เป็นหนึ่งในภาวะแทรกซ้อนที่สำคัญที่เพิ่มการเจ็บป่วยในผู้ป่วยธาลัสซีเมีย*

***วัตถุประสงค์:*** *เพื่อสร้างคะแนนความเสี่ยงสำหรับพยากรณ์ภาวะการสร้างเม็ดเลือดนอกไขกระดูกข้างไขสันหลังในผู้ป่วยธาลัสซีเมีย*

***วัสดุและวิธีการ:*** *การศึกษาย้อนหลังในผู้ป่วยธาลัสซีเมียที่โรงพยาบาลศรีนครินทร์ มหาวิทยาลัยขอนแก่น และโรงพยาบาลอุดรธานี ภาวะการสร้างเม็ดเลือดนอกไขกระดูกข้างไขสันหลังวินิจฉัยจากการมีหลักฐานทางรังสีวินิจฉัยของก้อนเลือดนอกไขกระดูกโดยอาจมีหรือไม่มีอาการทางคลินิกร่วมด้วย ปัจจัยทางคลินิกที่สัมพันธ์กับการเกิดภาวะดังกล่าวจะถูกนำมาวิเคราะห์ด้วยแบบจำลองการถดถอยโลจิสติค คะแนนความเสี่ยงได้มาจากค่าสัมประสิทธิ์ของตัวแปรในแบบจำลองสุดท้าย กราฟ ROC ถูกสร้างขึ้นเพื่อคำนวณพื้นที่ใต้โค้งและหาจุดตัดของคะแนนความเสี่ยง*

***ผลการศึกษา:*** *คะแนน KKU-EMH ประกอบด้วย 1) อายุมากกว่า 25 ปี (2 คะแนน) และ 2) ลักษณะหน้าตาธาลัสซีเมีย (3 คะแนน) เมื่อใช้จุดตัดที่ 5 คะแนน คะแนนความเสี่ยงนี้สามารถแยกผู้ป่วยตามความเสี่ยงได้โดยมีพื้นที่ใต้โค้งของกราฟ ROC เท่ากับ 0.83 (ช่วงความเชื่อมั่น 95% คือ 0.76 ถึง 0.90)*

***สรุป:*** *อายุที่มากและหน้าตาธาลัสซีเมียเป็นปัจจัยเสี่ยงสำหรับภาวะการสร้างเม็ดเลือดนอกไขกระดูกข้างไขสันหลังในผู้ป่วยโรคธาลัสซีเมีย คะแนน KKU-EMH เป็นคะแนนที่ใช้ได้จริง สามารถนำมาใช้ในการขัดกรองภาวะดังกล่าวในผู้ป่วยโรคธาลัสซีเมียชนิดบีตา*