Prevalence and Effect of Hemoglobin E Disorders on HbA1c and Lipid Profile of Diabetic Patients at Surin Hospital

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Objective: *To evaluate the prevalence of hemoglobin E disorders (HbE) and their characteristics in diabetic patients at Surin Hospital. Effects of HbE on HbA1c measurement and other variables in diabetic patients were also studied.*
Material and Method: *A cross-sectional study was performed. One thousand nine hundred seventy eight patients were recruited randomly using a systemic random sampling method. HbE screening test and Hb typing was performed. HbA1c was measured by turbidimetric inhibition immunoassay.*
Results: *The prevalence of homozygous HbE (HbEE) and HbE trait were 7.9% and 35.3% respectively. When compared with the negative screening group, the variables that were significantly higher in the HbEE group were hemoglobin A1c (HbA1c) < 6.5% ($p < 0.010$), HbA1c < 7% ($p < 0.010$), serum cholesterol level (CHOL) < 200 mg/dl ($p < 0.010$), low density lipoprotein (LDL) < 100 mg/dl ($p = 0.021$), and anemia by Hb measurement ($p < 0.010$). The adjusted odds ratio and 95% confidence interval (CI) of HbA1c < 6.5% and < 7% in HbEE when compared with the negative screening group were 5.16 (3.55-7.50) and 4.60 (3.04-6.97) respectively. The means of HbA1c, Hb, CHOL, and LDL in HbEE were significantly lower than the other groups ($p < 0.010$ in all variables). The adjusted odds ratio and 95% CI of HbA1c < 6.5% and < 7% in HbE trait when compared with the negative screening group were 1.12 (1.01-1.24) and 1.17 (1.06-1.29) respectively.*
Conclusion: *Hemoglobin E disorders are highly prevalent in diabetes patients at Surin Hospital. HbA1c, CHOL, and LDL were significantly lower in diabetic patients with HbEE.*

Keywords**:** *Hemoglobin E disorder, HbEE, HbE trait, Diabetes mellitus, DM, Surin Hospital*

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Hemoglobin E disorder (HbE) is one of the world's most common and important mutations[1-4]. HbE trait and homozygous HbE (HbEE) are mild disorders. HbE occurs in high frequency at the junction of Thailand, Laos, and Cambodia[5]. The resistance of HbE trait red cells to invasion by P falciparum is most likely the cause for its high prevalence throughout the world[6].

Hemoglobin A1c (HbA1c) is a marker of long-term glycemic control in patients with diabetes mellitus (DM) and is directly related to the risk of diabetic complications[7]. Lowering HbA1c close to the normal range has associated with a markedly decreased frequency and extent of microvascular and neuropathic complications in diabetic patients. Various diabetes associations have advocated HbA1c targets below 7% or 6.5% and fasting plasma glucose (FPG) levels below 130 mg/dl or 110 mg/dl[8-10]. HbE can affect the immunoassays used for HbA1c measurement. Some current HbA1c methods show clinically significant interference with samples containing HbE[11]. There were significant differences of HbA1c values between normal controls and hemoglobin E-containing samples[12].

The author evaluated the prevalence of HbE in the diabetes clinic at Surin Hospital, which is located in the northeastern region of Thailand and near the boundary of Cambodia. Effects of HbE on HbA1c measurement and other variables in diabetic patients were also studied.

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Material and Method

A cross-sectional study was conducted in the diabetes clinic at Surin Hospital between February 2009 and January 2010. The proposal was approved

by the Ethics Committee of Surin Hospital. The committee classified the proposal as R-to-R (routine to research study). The sample size was calculated from the population of 3,176 diabetic patients in the clinic[13]. One thousand nine hundred seventy eight patients were recruited randomly using a systemic random sampling method.

Inclusion criteria were diabetic patients followed in the clinic more than six months. At each visit, the patients were treated by physicians and a multidisciplinary team based on the American Diabetes Association (ADA) standard recommendations that consist of position statements that represent official ADA opinion as denoted by formal review and approval[8,14].

Exclusion criteria were blood loss from any cause within six months before data collection, active tuberculosis, renal failure, liver impairment, malignancy, known cases of hemolytic diseases other than HbE, or failure to follow the clinical practice guideline of the clinic.

FPG, HbA1c, lipid profile, complete blood count including hemoglobin concentration (Hb), BUN, creatinine, and dichlorophenol-indolephenol (DCIP) test were collected on the same day after the patients had been regularly treated for more than six months. Hemoglobin typing was performed in cases of positive DCIP test by Hb Gold analyzer (Drew Scientific Ltd., England) using low-pressure liquid chromatography (LPLC). The interpretation of HbE from Hb Gold chromatogram was based on hematologic data in various HbE syndromes[15]. HbA1c was measured by turbidimetric inhibition immunoassay and the reagent was Tina-Quant Hemoglobin A1c II Cobas. Lipid profile consists of serum cholesterol level (CHOL), triglyceride (TG), high-density lipoprotein (HDL) and low-density lipoprotein (LDL). CHOL and TG were measured by enzymatic colorimetric assay; the reagents were Cholesterol CHOD-PAP Cobas and Triglyceride GPO-PAP Cobas respectively. HDL and LDL were measured by homogenous enzymatic colorimetric assay; the reagents were HDL-C plus third generation Cobas and LDL-C plus second generation Cobas respectively. Both HbA1c and lipid profile were analyzed by Roche/Hitachi 917 automatic analyzer. The DCIP test was KKU-DCIP-Clear reagent[16].

Patients were classified into three groups: negative screening, HbE trait, and HbEE. There are various standards in the hemoglobin range[17,18], the cut-off point of anemia for each sex was classified by WHO standard[17].

Statistical analysis

Results were analyzed using SPSS for Windows version 11.0. Data were described in percentages, means, and standard deviations (SD). The Pearson Chi-square test was used to compare differences between nominal variables. Fisher's exact test and continuity correction were used when necessary. Two-tailed tests were used to determine the statistical significance at p-value less than 0.05. The odds ratio with 95% confidence interval (CI) of each nominal variable was calculated. The distributions of data were evaluated by Kolmogorov-Smirnov test. Kruskal-Wallis test was used to determine differences between means in each group. Stata version 6.0 was used to analyze logistic regression and adjusted odds ratio with 95% CI.

Results

One thousand nine hundred seventy eight diabetic patients in the diabetes clinic at Surin Hospital were studied in a one-year period between February 2009 and January 2010. Thirty point eight percent were male and 855 cases had HbE. The prevalence of HbEE and HbE trait were 7.9% and 35.3% respectively. In each group there was no difference between sex ($p = 0.740$), age under 60 years ($p = 0.866$) and body mass index (BMI) < 23 Kg/m^2 ($p = 0.453$). Diabetic patients with HbA1c reaching the target of < 6.5% and < 7% were highest in HbEE (67.5% with $p < 0.010$, 79.0% with $p < 0.010$ respectively), whereas the diabetic patients with FPG < 110 mg/dl or FPG < 130 mg/dl had no statistically significant difference between groups (Table 1). Diabetic patients with HbEE were significantly more anemic (78.3% in male and 80.2% in female) than the other groups ($p < 0.010$ both). There were no significant differences in means of age, length of DM, BMI, FPG, TG, HDL, BUN, or creatinine among the groups. The means of HbA1c, Hematocrit, Hb, CHOL, and LDL were significantly lower in HbEE (Table 2).

When compared with the negative screening group**,** diabetic patients with HbEE significantly had more HbA1c < 6.5% ($p < 0.010$), HbA1c < 7% ($p < 0.010$), CHOL< 200 mg/dl ($p < 0.010$), LDL < 100 mg/dl ($p = 0.021$), and anemia by various levels of Hb[17,18] ($p < 0.010$ in all categories). The crude odds ratio and 95% CI of HbA1c < 6.5% and < 7% in HbEE were 5.81 (4.05-8.32) and 5.20 (3.48-7.77) respectively (Table 3). The variables of BMI < 23 Kg/m^2, FPG < 110 mg/dl, FPG < 130 mg/dl, TG < 150 mg/dl, HDL > 40 mg/dl in males, and HDL > 50 mg/dl in females were not significantly different between groups.

Table 1. Prevalence of HbE disorders and the variables among each group

Characteristics	All (%)	Negative screening (%)	HbE trait (%)	HbEE (%)	p-value*
Cases	1,978	1,123 (56.8)	698 (35.3)	157 (7.9)	
Male/female	0.31	0.32	0.30	0.29	0.740
Age under 60 years	1,096 (55.4)	606 (54.0)	405 (58.0)	85 (54.1)	0.225
BMI < 23 kg/m^2	854 (44.2)	494 (44.9)	228 (42.4)	72 (47.1)	0.453
FPG < 110 mg/dl	406 (20.5)	225 (20.0)	143 (20.5)	38 (24.2)	0.480
FPG < 130 mg/dl	920 (46.5)	506 (45.1)	341 (48.9)	73 (46.5)	0.287
HbA1c < 6.5%	619 (31.3)	296 (26.4)	217 (31.1)	106 (67.5)	<0.010
HbA1c < 7.0%	994 (47.7)	471 (41.9)	349 (50.0)	124 (79.0)	<0.010
Hb < 13 g/dl in male	240 (39.3)	121 (34.2)	83 (39.5)	36 (78.3)	<0.010
Hb < 12 g/dl in female	719 (52.6)	370 (48.1)	260 (53.3)	89 (80.2)	<0.010

* Pearson Chi-square

HbE = hemoglobin E disorder; HbEE = homozygous HbE; HbA1c = hemoglobin A1c; BMI = body mass index; FPG = fasting plasma glucose

Table 2. Means and standard deviations of the variables of each group

Characteristics	All Mean (SD)	Negative screening Mean (SD)	HbE trait Mean (SD)	HbEE Mean (SD)	p-value*
Age (year)	58.70 (11.1)	59.00 (11.3)	58.30 (10.9)	58.70 (10.1)	0.223
Length of DM (year)	5.21 (2.98)	5.11 (2.55)	5.30 (3.42)	5.54 (3.68)	0.757
BMI (kg/m^2)	23.90 (4.16)	23.80 (4.18)	24.00 (4.20)	23.30 (3.82)	0.138
FPG (mg/dl)	142.60 (48.9)	143.40 (50.2)	141.20 (46.3)	143.00 (50.6)	0.712
HbA1c (%)	7.50 (1.88)	7.69 (1.95)	7.43 (1.76)	6.47 (1.51)	<0.010
Hematocrit (%)	37.50 (4.87)	38.50 (7.75)	37.10 (4.46)	32.40 (4.00)	<0.010
Hb (g/dl)	12.20 (1.72)	12.40 (1.74)	12.10 (1.62)	11.00 (1.50)	<0.010
CHOL (mg/dl)	198.60 (43.6)	198.90 (42.5)	201.50 (46.0)	182.90 (36.5)	<0.010
TG (mg/dl)	175.90 (110.4)	176.40 (113.6)	178.50 (109.9)	160.60 (86.0)	0.155
LDL (mg/dl)	121.40 (37.9)	121.20 (37.1)	124.60 (39.8)	109.10 (31.5)	<0.010
HDL in male (mg/dl)	47.00 (13.6)	47.40 (14.1)	47.10 (13.2)	44.40 (10.9)	0.349
HDL in female (mg/dl)	50.70 (12.8)	50.70 (12.9)	50.50 (11.8)	51.60 (16.0)	0.928

* Kruskal Wallis test

CHOL = cholesterol level; TG = triglyceride; LDL = low density lipoprotein; HDL = high density lipoprotein; Hb = hemoglobin concentration; BMI = body mass index; FPG = fasting plasma glucose

When compared with the negative screening group, diabetic patients with HbE trait significantly had more HbA1c < 6.5% (p = 0.029), HbA1c < 7% (p = 0.001), there were no significant differences of anemia in each sex. The crude odds ratio and 95% CI of HbA1c < 6.5% and < 7% in HbE trait were 1.26 (1.02-1.55) and 1.38 (1.15-1.67) respectively (Table 3).

Logistic regression

Between negative screening group and diabetic patients with HbEE, logistic regression showed the models:

Logistic HbA1c < 6.5% HbEE DM < 5 years Age < 60 years Anemia

Logistic HbA1c < 7% HbEE DM < 5 years Age < 60 years Anemia LDL < 100 mg/dl

Between negative screening group and diabetic patients with HbE trait, logistic regression showed the models:

Logistic HbA1c < 6.5% HbE trait DM < 5 years Age < 60 years Anemia LDL< 100 mg/dl

Logistic HbA1c < 7% HbE trait DM < 5 years Age < 60 years Anemia LDL < 100 mg/dl

The adjusted odds ratio and 95% CI of HbA1c < 6.5% and < 7% in HbEE were 5.16 (3.55-7.50) and 4.60 (3.04-6.97) respectively. The adjusted odds ratio and 95% CI of HbA1c < 6.5% and < 7% in HbE trait were 1.12 (1.01-1.24) and 1.17 (1.06-1.29) respectively.

Table 3. Crude odds ratios of DM with HbEE and HbE trait compared with the group of DM with negative screening

	HbEE		HbE trait	
	Odds ratio	95% of CI	Odds ratio	95% of CI
HbA1c < 6.5%	5.81	4.05-8.32	1.26	1.02-1.55
HbA1c < 7.0%	5.20	3.48-7.77	1.38	1.15-1.67
BMI < 23 kg/m^2	1.09	0.78-1.53	0.91	0.75-1.10
FPG < 110 mg/dl	1.27	0.86-1.89	1.03	0.81-1.30
FPG < 130 mg/dl	1.06	0.76-1.48	1.17	0.96-1.41
TG < 150 mg/dl	1.37	0.98-1.92	0.97	0.80-1.18
CHOL < 200 mg/dl	2.04	1.42-2.94	0.97	0.80-1.17
LDL < 100 mg/dl	1.50	1.06-2.12	0.91	0.74-1.12
HDL > 40 mg/dl in male	0.64	0.34-1.21	0.87	0.60-1.26
HDL > 50 mg/dl in female	1.19	0.80-1.78	0.96	0.76-1.20
Hb < 13 g/dl in male	6.93	3.33-14.45	1.26	0.88-1.79
Hb < 12 g/dl in female	4.36	2.68-7.10	1.23	0.98-1.54

DM = diabetes mellitus

Discussion

Intensive glucose therapy in patients with newly diagnosed type 2 DM was associated with a reduced risk of microvascular complications[7]. Measuring HbA1c levels is recommended in all clinical practice guidelines of DM because it directly relates to such complications. Turbidimetric inhibition immunoassay is widely used to measure HbA1c levels in the hospitals of Thailand. Surin province, which is an endemic area for HbE disorder, also uses this method.

The present study shows results of HbA1c in diabetic patients with HbE using this immunoassay. From the original study of DCIP test in Thai-Khmer individuals living in the provinces of Surin and Burirum, the DCIP test had 100% sensitivity and 98.7% specificity for HbE with 98.6% positive predictive value and 100% negative predictive value[16]. The ratio of HbE trait and HbEE in the study did not differ from the present. According to the present data, there should not be the possibility of misinterpretation to be negative screening and only one false positive case was seen in the present study. However, the sensitivity and specificity of DCIP test for HbE in a recent study were 97.16% and 98.93%, the combination of DCIP test and mean corpuscular volume (MCV) < 80 fL as screening test can increase the sensitivity[19]. This combination was applied in the diabetic clinic at Surin Hospital and the results in some aspects including economy will be evaluated. Neither the similarity of sensitivity and specificity of DCIP test between HbEE and HbE trait nor the ratio of HbEE and HbE trait was clarified in a recent large scale study[19].

Although Hb typing was not performed in all cases of the negative screening group, this group had few contaminations with the other types of hemoglobinopathy referred to in the previous data[20]. However, all subjects in the clinic should be tested for Hb typing and serum iron in a future study when the author's budget allows.

The prevalence of HbE in the diabetes clinic at Surin Hospital is very high. In pregnant women, the prevalence of HbEE and HbE trait at Surin Hospital were 9.0% and 38.2% whereas at Maharaj Nakorn Chiang Mai Hospital were 0.8% and 13.1% respectively[20,21]. The prevalence of HbE in diabetic patients and pregnant women at Surin Hospital did not much differ.

There were significant differences in HbA1c values between the negative screening and HbE disorder groups, especially in HbEE. The odds ratios of patients reaching HbA1c targets compared to the negative screening group were significantly more than five times in HbEE, whereas the patients reaching FPG targets had no significant difference between them (Table 3). Whether this observation was due to interference or better glycemic control could not be determined. However, the interpretation of glycemic control using HbA1c in the endemic area for HbE should be carefully considered if current HbA1c measuring method has interference with samples containing HbE. Since measuring HbA1c by high performance liquid chromatography in HbEE also has significant interference[22], both screening for HbE in

diabetic patients and identifying HbEE in positive cases are necessary in endemic areas. Alternative parameters to evaluate long-term glycemic control in HbEE patients should also be created.

The means of CHOL and LDL were lowest in HbEE (Table 2), and those of reaching targets for CHOL and LDL were significantly higher in HbEE (Table 3). Normal lipid composition and organization is lost in some subpopulations of RBC in hemoglobinopathies[23], whether the finding of low CHOL and LDL levels in HbEE relate to this characteristic. Oxidative modification of lipoproteins had been reported in beta-thalassemia/HbE and had been suggested to relate to atherogenesis risk. The reduction of cholesteryl linoleate can be used as a severity index[24]. The benefit of finding low CHOL and LDL levels in diabetic patients with HbEE is doubtful. Further study should be performed to determine the origins and vascular outcomes.

Conclusion

Hemoglobin E disorders are highly prevalent in diabetes patients at Surin Hospital. HbA1c, CHOL, and LDL were significantly lower in diabetic patients with HbEE. The identification of diabetic patients with HbEE in endemic areas is necessary if current HbA1c measuring method has interference with samples containing HbE.

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Potential conflict of interest

None.

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ความชุก และผลของฮีโมโกลบินอีต่อฮีโมโกลบิน เอวันซี และ lipid profile ในผู้ป่วยเบาหวานที่โรงพยาบาลสุรินทร์

วสันต์ ศรีสุรินทร์

วัตถุประสงค์*: เพื่อค้นหาความชุกของฮีโมโกลบิน อี ในผู้ป่วยเบาหวานของคลินิกเบาหวานโรงพยาบาลสุรินทร์ และศึกษาคุณลักษณะของผู้ป่วยเบาหวานที่มีฮีโมโกลบิน อี*

วัสดุและวิธีการ*: ทำการศึกษาภาคตัดขวางโดยวิธีสุ่มตัวอย่างแบบมีระบบจำนวน 1,978 คน จากผู้ป่วยทั้งหมด 3,176 คน ตั้งแต่เดือนกุมภาพันธ์ พ.ศ. 2552 ถึงเดือนมกราคม พ.ศ. 2553 ตรวจคัดกรองเพื่อค้นหาฮีโมโกลบิน อี แล้วส่งตรวจยืนยันโดยการตรวจหาชนิดของฮีโมโกลบินด้วยวิธีมาตรฐาน ตรวจวัดฮีโมโกลบินเอวันซีโดยวิธียับยั้งความขุ่นด้วยแอนติบอดี*

ผลการศึกษา*: พบค่าความชุกของโรคโลหิตจางธาลัสซีเมียชนิดอี ร้อยละ 7.9 และฮีโมโกลบิน อี แฝงร้อยละ 35.3 เมื่อเปรียบเทียบกับกลุ่มที่การตรวจคัดกรองให้ผลลบ ตัวแปรในกลุ่มโรคโลหิตจางธาลัสซีเมีย ชนิดอีที่พบสูงกว่าอย่างมีนัยสำคัญทางสถิติได้แก่ จำนวนผู้มีค่าฮีโมโกลบินเอวันซีน้อยกว่า 6.5% ($p < 0.010$), ฮีโมโกลบินเอวันซีน้อยกว่า 7% ($p < 0.010$), คอเลสเตอรอลในเลือดน้อยกว่า 200 มิลลิกรัมต่อเดซิลิตร ($p < 0.010$), แอลดีแอลน้อยกว่า 100 มิลลิกรัมต่อเดซิลิตร ($p = 0.021$) และภาวะโลหิตจาง ($p < 0.010$) ตามลำดับ โดยค่า odds ratio เมื่อปรับค่าแล้ว และค่าความเชื่อมั่น 95% ของฮีโมโกลบินเอวันซีน้อยกว่า 6.5% และ 7% ในโรคโลหิตจางธาลัสซีเมียชนิดอี เมื่อเปรียบเทียบกับกลุ่มที่การตรวจคัดกรองให้ผลลบ คือ 5.16 (3.55-7.50) และ 4.60 (3.04-6.97) ตามลำดับ ค่าเฉลี่ยของฮีโมโกลบินเอวันซี, ฮีโมโกลบิน, คอเลสเตอรอล และแอลดีแอลในกลุ่มโรคโลหิตจางธาลัสซีเมียชนิดอีต่ำกว่ากลุ่มอื่นอย่างมีนัยสำคัญทางสถิติ โดยทั้งหมดมีค่า $p < 0.010$ ค่า odds ratio เมื่อปรับค่าแล้ว และค่า ความเชื่อมั่น 95% ของฮีโมโกลบินเอวันซีน้อยกว่า 6.5% และ 7% ในฮีโมโกลบินอีแฝง เมื่อเปรียบเทียบกับกลุ่มที่การตรวจคัดกรองให้ผลลบ คือ 1.12 (1.01-1.24) และ 1.17 (1.06-1.29) ตามลำดับ*

สรุป*: พบผู้มีฮีโมโกลบินอีสูงในผู้ป่วยเบาหวานของโรงพยาบาลสุรินทร์ ในผู้ป่วยเบาหวานที่เป็นโรคโลหิตจางธาลัสซีเมียชนิดอี เมื่อเปรียบเทียบกับกลุ่มที่การตรวจคัดกรองให้ผลลบ พบผลการตรวจวัดฮีโมโกลบินเอวันซี ด้วยวิธียับยั้งความขุ่นด้วยแอนติบอดี, คอเลสเตอรอล และแอลดีแอลต่ำกว่าอย่างมีนัยสำคัญทางสถิติ*