



ORIGINAL ARTICLE

Use of Capillary Electrophoresis for Detection of Hemoglobinopathies in Individuals Referred to Health Centers in Masjed-Soleiman

Seyedeh Moloud Rasouli Ghahfarokhi¹, Fatemeh Asadi^{2*}, Narges Obeidi³

¹Department of Nursing and Midwifery, Masjed-Soleiman Branch, Islamic Azad University, Masjed Soleiman, Iran

²Department of Genetic, Masjed-Soleiman Branch, Islamic Azad University, Masjed-Soleiman, Iran

³Department of Hematology, School of Para Medicine, Bushehr University of Medical Sciences, Bushehr, Iran

ARTICLE INFO

Article History:

Received: 16.03.2017

Accepted: 10.07.2017

Keywords:

Hemoglobinopathy
Capillary electrophoresis
Hemoglobin variants
Beta thalassemia mutations

*Corresponding author:

Fatemeh Asadi
Department of Genetic, Masjed-Soleiman Branch,
Islamic Azad University, Masjed-Soleiman, Iran
Email: Fatemehasadi@miau.ac.ir

ABSTRACT

Background: Hemoglobinopathies are the commonest single gene disorder in human that affect hemoglobin production and function that occur when mutations alter the amino acid sequence of globin chains. The purpose of the present study was to evaluate the prevalence of hemoglobinopathies detected by capillary electrophoresis method in individuals referred to Masjed-Soleiman health centers by capillary electrophoresis method.

Methods: This study was carried out on 394 individuals referred to Masjed-Soleiman health centers during 2015-2016. Blood samples were collected in EDTA vacutainer tubes, then CBC including blood indexes (MCV, MCH), level of Hemoglobin A, Hb F, Hb A2 and other hemoglobins were evaluated by Sebia minicap (France) and also genetic tests applied for them to confirm results that were acquired by capillary electrophoresis method.

Results: 77 (19.5%) subjects had HbA2 \geq 3.5%, thus were classified as beta thalassemia carrier and 3.3%, 2.5%, 1.5% and 0.5% of the individuals were heterozygote for Hb S, Hb D, Hb C and Hb Bart, respectively. Results of the genetic analysis showed the mutations in these subjects; cd36-37(-T) was the most frequent mutation in beta thalassemia carriers in this geographic region.

Conclusion: This study showed high frequency of beta thalassemia mutations in the geographic region of Masjed-Soleiman (19.5), and 7.85% of the individuals had hemoglobin variants including Hb S, Hb D and Hb C detected by capillary electrophoresis. Capillary electrophoresis could be a considerable method for detection of hemoglobinopathies.

Please cite this article as: Rasouli Ghahfarokhi SM, Asadi F, Obeidi N. Use of Capillary Electrophoresis for Detection of Hemoglobinopathies in Individuals Referred to Health Centers in Masjed-Soleiman. IJBC 2017; 9(3): 89-92.

Introduction

Inherited hemoglobin disorders known as hemoglobinopathies are caused by mutations of the globin genes. Globin chain is made up of four polypeptide chains; these chains are of four types: α , β , δ , and γ . Each molecule of hemoglobin consists of two pairs of unlike globin chains. The hemoglobin disorders fall into two main groups: the structural hemoglobin variants and the thalassemia. Single nucleotide substitutions can lead to hemoglobin variants or hemoglobinopathies. In normal

adults, 96-98% of the Hb is Hb A ($\alpha_2\beta_2$), with small amounts (23.5%) of HbA2 ($\alpha_2\delta_2$) and about 1.5 % of Hb F ($\alpha_2\gamma_2$).¹

According to recent statistics, approximately 7% of the global population carries an inherited Hb disorder gene and about 500,000 infants are born with a severe hemoglobin disorder annually.² Currently, up to 1000 hemoglobin variants have been registered.³ Some of the hemoglobin variants are common such as Hb S (the most common worldwide), Hb C, Hb E and Hb D-Punjab.⁴

Likewise, other hemoglobin variants such as D, S, C, Lepore, Setif, CS, Q, J and other hemoglobins have been reported in many countries including Iran.⁵

β -thalassemia is commonly observed in individuals of Mediterranean, African, and Southeast Asian ancestry. In Iran the gene frequency of β -thalassemia mutations is high and varies from area to area. In southern Iran, the gene frequency is also high and is about 8-10%.⁶ As a result, diagnosis of hemoglobin variants and thalassemia has become increasingly important in clinical laboratories. In agreement with the guidelines of the British Committee for Standards in Hematology, numerous techniques for the screening and diagnosis of hemoglobinopathies have been developed such as cellulose acetate electrophoresis (CAE), isoelectric focusing (IEF), low-pressure liquid chromatography (LPLC), high-performance liquid chromatography (HPLC), capillary zone electrophoresis (CZE) and finally genetic analysis.⁷ Cellulose acetate method is a common method for detection of hemoglobinopathies; however, differentiation of Hb variants with low concentrations, especially unstable hemoglobin can be difficult.

HPLC is a useful method for screening and diagnosis of hemoglobinopathies, but interference of glycated Hb S and Hb E with HbA2 quantitation may result in incorrect diagnosis of beta thalassemia in the presence of glycated Hb S and Hb E.^{8,9} In 2007, Food and Drug Administration (FDA) approved the Sebia Capillarys CZE system for the evaluation of hemoglobinopathies.¹⁰

Reliable evidence has indicated that CZE may be an accurate tool for the screening and diagnosis of hemoglobinopathies. You-Qiong and colleagues analyzed adult and cord blood sample of patients heterozygous for Hb New York by using both CZE and HPLC. Interestingly, all cases could be diagnosed with CZE, whereas none of them could be detected by HPLC.¹¹

Masjed-Soleiman is located in southern Iran (Khuzestan province) and the Bakhtiar population is the prominent ethnic group in this area. The frequency of the

consanguineous marriage is high in there. We aimed to evaluate the prevalence of hemoglobinopathies in this population by capillary electrophoresis.

Material and Methods

This study was carried out on 394 individuals (51 %men and 49% women) that were referred to Masjed-Soleiman health center during 2015-2016. Blood samples were collected in EDTA vacutainer tubes, then CBC including blood indexes (MCV, MCH) were performed and hemoglobin A, Hb F, Hb A2 and other hemoglobin variants were evaluated by capillary electrophoresis (CE).

CE was performed using the Minicap system according to manufacturer's guidelines. The instrument is equipped to re-suspend, lyse, separate, and analyze EDTA whole blood for hemoglobin variants. Samples were tracked using a built-in bar code reader and electropherograms were produced automatically. The lysed red cells are electrophoresed in alkaline buffer (pH 9.4) allowing separation to be directed by pH and endosmosis. Detection of eluting hemoglobin species is accomplished using the change in absorbance 415 nm. An electropherogram is divided into 15 zones that each zone is entitled as Z.¹² Then genetic analysis including, ARMS-PCR, RFLP-PCR and sanger sequencing applied for confirming the results of CE method.

Results

77 of 394 samples (19.5%) showed Hb A2 >3.5 %, thus were classified as beta thalassemia carrier state. 74(18.7%) of them had MCV<80.0 fL, MCH<27.0 pg, but 3(0.75%) had normal blood indexes (MCV, MCH). The genetic analysis revealed various mutations in minor beta thalassemia; the most frequent was cd 36-37(-T) (table 1).

There were individuals who were heterozygote for Hb S, Hb D, Hb C and Hb Bart while their blood indexes were in normal range (table 2). The genetic analysis for these variants showed mutations in the β -globin gene, HBB: c.20A>T), HBB: c.67G> C and HBB:c.19G>A in

Table 1: Blood Indexes and mean and standard deviation of hemoglobin variants

Indexes of blood	Hemoglobin variants	Mean percent \pm SD	Frequency No (%)
MCV \geq 80,MCH \geq 27	Hb S	16.22 \pm 3.8	12 (3.3)
MCV \geq 80,MCH \geq 27	Hb D	35.57 \pm 13.7	10 (2.53)
MCV \geq 80,MCH \geq 27	Hb C	8.13 \pm 2.46	4 (1.52)
MCV<80,MCH< 27	Hb Bart	1.1 \pm .49	2 (0.5)
Total			28 (7.85)

Table 2: Frequency of Mutations of Beta thalassemia

Type of mutations of beta thalassemia	Number	Frequency
cd 36-37(-T)	28	36.36%
IVSII-1 (G>A)	16	20.77%
IVSI-110(G>A)	11	14.28%
Cd 82-83(-G)	8	10.38%
5UTR+20(C>T)	6	7.79%
IVS II-745(C>G)	4	5.19%
cd82-83(-G)	3	3.89%
Fr 8.9	1	1.29
Total	77	100%

Hb S, Hb D and Hb C, respectively.

The subjects with Hb A2 < 3.5% could be suspected of having a thalassemia or iron deficiency or association of β thalassemia with iron deficiency.

Discussion

Khuzestan province is a province with high frequency of mutations for alpha and beta thalassemia and hemoglobinopathies C, S and D.¹³ Hemoglobin D is a beta chain variant, observed mainly in northwest India, Pakistan and Iran (south, north, and west of Iran).¹⁴ Hb D could be seen in combination with sickle hemoglobin and beta thalassemia. Co-inheritance of beta-thalassemia and Hb D together can result in the slightly lower hemoglobin levels.

Hb S results from a point mutation in beta globin chain gene. Sickle cell disease is very frequent in southern of Iran, especially in Khuzestan province that sickle cell trait is usually asymptomatic with normal RBC indexes.¹⁵ On the other hand, measurement of Hb A2 is challenging because its level could be low and also interference with other hemoglobin variants would change the quantity of Hb A2 and since molecular techniques are not routinely used in many medical laboratories, so that the most unknown hemoglobin variants may not be correctly diagnosed.¹⁶

The aim of this study was screening of hemoglobin abnormalities by using of capillary zone electrophoresis. In this study 19.5% of the individuals were classified as beta thalassemia carriers. 3.3%, 2.5%, 1.5% and 0.5% of the subjects were heterozygote for Hb S, Hb D, Hb C and Hb batrs, respectively. The numbers approximately were similar to the study performed by Joshaghani and colleagues in North of Iran. In that study, Hb electrophoresis was carried out by capillary electrophoresis and 0.27%, 4.68%, 55%, 0.27% and 0.41% were recorded for Hb E, Hb D, Hb S, Hb H and Hb Bart, respectively. In that study, Hb D had a higher frequency than our study.¹⁷ We did not have any case of Hb E in our samples.

Zandian et al. studied frequency of alpha and beta thalassemia mutations and hemoglobin C, D, and S in Ahvaz. Hemoglobin S was the most frequent hemoglobinopathy that was similar to our study.¹³

In another study which was performed in Ahwaz, the frequency of alpha and beta thalassemia and other hemoglobinopathies was investigated. The Results of their study showed the frequency of Hb S, D, C, and α -globin gene mutations to be 16.2%, 3.2%, 1%, and 9.7%, respectively which again was similar to the present study.¹⁸

In the present study, we used capillary zone electrophoresis for detection of hemoglobinopathies. Recent studies have illustrated that capillary electrophoresis separates HbA2 well from Hb E, Hb C, and Hb S and is suitable for screening. Cellular acetate electrophoresis is routinely used in clinical laboratory; however, is not much accurate. On the other hand, HPLC method is costly and not routinely available. It can achieve simultaneous analysis, fast separation, good resolution,

high accuracy, and full automation. Furthermore, capillary electrophoresis also is capable to separate Hb A2 from Hb Lepore than the HPLC method.¹⁹

kim et al. compared the capillary electrophoresis method with cellulose acetate method for screening of hemoglobinopathies. The study was performed in two groups, one group with normal CBC and the other group were subjects with hypochromia and microcytosis. No statistically significant difference was found for Hb quantification ($P>0.05$). The study indicated that capillary electrophoresis was more sensitive than cellulose acetate for detecting Hb fractions.²⁰

Higgins and coworkers analyzed evaluation of Hb A2 in patients with and without beta-thalassemia, and assessed heterozygous patients for Hb E, Hb S, Hb C and Hb D Punjab by using of capillary system. The results of this study demonstrated that the capillary method is superior to the Variant II method for HbA2 quantified measurement.²¹

Weykamp et al. evaluated the analytical interference of Hb S, Hb C, Hb D, Hb E, Hb J and Hb G on Hb A1c accuracy and concluded that glycosylated Hb could be reliably measured with CZE.²²

In another study, Pornprasert et al. developed specific quality control materials for analysis of some forms of thalassemia and Hb variants that are commonly observed in South-East Asia. Interestingly, the Hb typing control materials could be stored and then accurately analyzed by the many commercially available techniques, including HPLC and CZE, thus representing a valuable resource for internal and external quality assurance in the diagnosis of hemoglobinopathies.²³

In another investigation by Wan Asmuni and coworkers, cord blood was used for Hb E screening through capillary electrophoresis. It showed that implementation of a screening strategy using capillary electrophoresis on cord blood samples in areas where Hb E hemoglobinopathy is prevalent, is highly recommended as it is feasible and the disorder would be detected earlier in life.²⁴

Conclusion

This study showed high frequency of beta thalassemia (19.5%) and other hemoglobin variants including Hb S, Hb D and Hb C in Masjed-Soleiman region and also indicated that capillary electrophoresis could be a considerable method for detection of hemoglobinopathies.

Funding

This research was funded Islamic Azad University, Science and Research Branch, Masjed soleiman.

Ethical Approval

The Ethics Committee of Islamic Azad University, Masjed Soleiman Branch approved the study.

Conflict of Interest: None declared.

References

1. Weatherall D, Akinyanju O, Fucharoen S, Olivieri N, Musgrove P. Inherited disorders of hemoglobin.

- In: Jamison DT, Breman JG, Measham AR, Alleyne G, Claeson M, Evans DB, et al., editors. Disease control priorities in developing countries, 2nd ed. Washington (DC): World Bank and Oxford University Press; 2006. Chapter 34.
2. Weatherall DJ, Clegg JB. The Thalassaemia Syndromes. 4th ed. Oxford: Blackwell Scientific Publication; 2008. doi: 10.1002/9780470696705.
 3. HbVar: A database of human hemoglobin variants and thalassemias. Available from: <http://globin.cse.psu.edu/hbvar/menu.html>
 4. Giordano PC. Strategies for basic laboratory diagnostics of the hemoglobinopathies in multi-ethnic societies: interpretation of results and pitfalls. *Int J Lab Hematol*. 2013; 35(5):465-79. PubMed PMID: 23217050. doi: 10.1111/ijlh.12037.
 5. Hajizamani S, Jalalifar, Kaveh Jaseb MA, Jaseb K, Saki N. A review of rare hemoglobinopathies in Iran. *G3M*. 2013; 11(3):3206-17.
 6. Haghshenas M, Zamani J. [Thalassemia]. 1st ed. Shiraz: Shiraz University of Medical Sciences Publishing Center; 1997.
 7. Ryan K, Bain BJ, Worthington D, James J, Plews D, Mason A, et al. Significant haemoglobinopathies: guidelines for screening and diagnosis. *Br J Haematol*. 2010; 149(1):35-49. doi: 10.1111/j.1365-2141.2009.08054.x.
 8. Wajcman H, Moradkhani K. Abnormal haemoglobins: detection & characterization. *Indian J Med Res*. 2011; 134(4): 538-46. PubMed Central PMCID: PMC3237254.
 9. Kalleas C, Tentes I, Margaritis D, Anagnostopoulos K, Toli A, Pendilas D, et al. Effect of HbS in the determination of HbA2 with the Biorad Variant II analyzer. *Clin Biochem*. 2007; 40(9-10):744-6. doi: 10.1016/j.clinbiochem.2007.03.008.
 10. Keren DF, Hedstrom D, Gulbranson R, Ou CN, Bak R. Comparison of Sebia capillary electrophoresis with the primus high-performance liquid chromatography in the evaluation of hemoglobinopathies. *Am J Clin Pathol*. 2008; 130(5): 824-31.
 11. You-Qiong L, Hui-Ping H, Zhi-Zhong C, Lin Z, Liang L, Gui-Fang Q, et al. Comparison of capillary electrophoresis and high performance liquid chromatography for detection and quantification of hemoglobin New York. *Clin Chem Lab Med*. 2016; 54(1):91-5. doi: 10.1515/cclm-2015-0238. PubMed PMID: 26053012.
 12. Cotton F, Malaviolle X, Vertongen F, Gulbis B. Evaluation of an automated capillary electrophoresis system in the screening for hemoglobinopathies. *Clin Lab*. 2009; 55(5-6):217-21. PubMed PMID: 19728555.
 13. Zandian K, Pedram M, Keykhaei B. The diagnosis and frequency of beta and alpha thalassemia mutations and other C, D, and S common hemobinopathies in Ahvaz volunteer patients. *Persian Journal of Medical Sciences (PJMS)*. 2014; 1(1):23-6.
 14. Saleh-Gohari N, Mohammadi-Anaie M. Co-inheritance of sickle cell trait and thalassemia mutations in South central Iran. *Iran J Public Health*. 2012; 41(10):81-6. PubMed Central PMCID: PMC3494235.
 15. Zandian K, Pedram M. Iran sickle cell & thalassemia screening program: A pilot study on 50 Sickle cell trait. *Jundishapur Scientific Medical Journal*. 2002; 33.
 16. Yang Z, Chaffin CH, Easley PL, Thigpen B, Reddy VV. Prevalence of elevated hemoglobin A2 measured by the CAPILLARYS system. *Am J Clin Pathol*. 2009;131(1):42-8. doi: 10.1309/AJCPD0PJGFT0SXMK. PubMed PMID: 19095564.
 17. Joshaghani HR, Parvizi S, Kalavi K, Behnampour N, Joshaghani H, Hashemi N, et al. Hemoglobin D is the most Common Hemoglobinopathy in the North of Iran. *Medical Laboratory Journal*. 2015; 9(5):28-32.
 18. Zandian K, Keikhaei B, Pedram M, Kianpoor Ghahfarokhi F. Prenatal diagnosis and frequency determination of alpha and beta Thalassemia, S, D and C Hemoglobinopathies, globins Globin Mutational Genes Analysis among Voluntary Couples from Ahvaz. *IJBC*. 2007; 1(3):95-8.
 19. Giambona A, Passarello C, Renda D, Maggio A. The significance of the hemoglobin A₂ value in screening for hemoglobinopathies. *Clin Biochem*. 2009; 42(18):1786-96. doi: 10.1016/j.clinbiochem.2009.06.026. PubMed PMID: 19591816.
 20. Kim JE, Kim BR, Woo KS, Kim JM, Park JI, Han JY. Comparison of capillary electrophoresis with cellulose acetate electrophoresis for the screening of hemoglobinopathies. *Korean J Lab Med*. 2011; 31(4):238-43. doi: 10.3343/kjlm.2011.31.4.238. PubMed PMID: 22016676. PubMed Central PMCID: PMC3190001.
 21. Higgins TN, Khajuria A, Mack M. Quantification of HbA2 in patients with and without β -thalassemia and in the presence of HbS, HbC, HbE, and HbD Punjab hemoglobin variants comparison of two systems. *Am J Clin Pathol*. 2009; 131(3):357-62. doi: 10.1309/AJCP28QKSOPHYOBC. PubMed PMID: 19233839.
 22. Weykamp C, Kemna E, Leppink S, Siebelder C. Glycation rate of haemoglobins S, C, D, E, J and G, and analytical interference on the measurement of HbA1c with affinity chromatography and capillary electrophoresis. *Clin Chem Lab Med*. 2015; 53(9):e207-10. doi: 10.1515/cclm-2014-1134. PubMed PMID: 25719326.
 23. Pornprasert S, Tookjai M, Punyamung M, Pongpunyayuen P, Jaiping K. Development of hemoglobin typing control materials for laboratory investigation of thalassemia and hemoglobinopathies. *Clin Chem Lab Med*. 2016; 54(1):81-9. doi: 10.1515/cclm-2015-0113. PubMed PMID: 25996485.
 24. Wan Mohd Saman WA, Hassan R, Mohd Yusoff S, Che Yaakob CA, Abdullah NA, Ghazali S, et al. Potential use of cord blood for Hb E hemoglobinopathy screening programme using capillary electrophoresis. *Malays J Pathol*. 2016; 38(3):235-39. PubMed PMID: 28028293.