

Genotyping of Intron 22 and Intron 1 Inversions of Factor VIII Gene Using an Inverse-Shifting PCR Method in an Iranian Family with Severe Haemophilia A

Fatemeh Sarkargar MSc¹, Mahta Mazaheri MD PhD^{2,3*}, Hossein Khodai BSc⁴, Razieh Sadat Tabatabaei MD⁵

1. PhD student of Biochemistry, Department of Biology, Faculty of Science, Payamnoor -University, Tehran, Iran

2. Associate Professor of Medical Genetics (MD-PhD), Department of Genetics, Faculty of Medicine, Shahid Sadoughi University of Medical Science, Yazd, Iran.

3. Mother and Newborn Health Research Center, Shahid Sadoughi University of Medical Science, Yazd, Iran

4. Expert Laboratory of Genetic, Meybod Genetic Research Center, Meybod, Iran

5. Assistant Professor of Gynecology, Department of Gynecology and Obstetrics, Faculty of Medicine, Shahid Sadoughi University of Medical Science, Yazd, Iran.

*Corresponding author: Mahta Mazaheri, Faculty of Medicine, Department of Genetics, Shahid Sadoughi University of Medical Science, Yazd, Iran. Email: m.mazaheri@ssu.ac.ir

Received: 26 March 2016

Accepted: 10 July 2016

Abstract

Background: Haemophilia A (HA) is an X-linked bleeding disorder caused by the absence or reduced activity of coagulation factor VIII (FVIII). Coagulation factors are a group of related proteins that are essential for the formation of blood clots. The aim of this study was to genotype the coagulation factor VIII gene mutations using Inverse Shifting PCR (IS-PCR) in an Iranian family with severe Haemophilia A.

Material and Methods: Genomic DNA was extracted from blood of Iranian family members with severe hemophilia A and then was genotyped using specific primers by Inverse Shifting PCR method and was analyzed by sequencing for all FVIII exons.

Results: Sequence analysis of *F8* gene revealed two distinct mutations. The first mutation was a C-to-G transition at 3780 position in exon 14, which cause an Asp1240 Glu in the region encoding the B domain of FVIII. It seems that this mutation could be a polymorphism. The second mutation was a 2-bp AA deletion in exon 18 (nt. 5820-5823, del. AA). The patient's mother and sister were also heterozygous for 2bp AA deletion. This deletion caused a frame shift in exon 18 and terminated after 29 amino acids for a premature stop codon.

Conclusions: Based on the results, it can be concluded that two IS-PCR and genomic sequencing techniques are robust and low cost method that facilitates the analysis of HA patients and carrier detection.

Key words: Hemophilia A, Coagulation Factor VIII Gene, mutation

Introduction

Haemophilia A (HA) is an X-linked bleeding disorder caused by the absence or reduced activity of coagulation factor VIII (FVIII) (1). Coagulation factors are a group of related proteins that are essential for the formation of blood clots (2). Factor VIII deficiency is caused by broad spectrum mutations, which occurs along the entire length of the factor VIII gene. Mutation in *F8* gene includes the intron 22 and intron 1 inversion, point mutations (nonsense and missense mutations), deletions, and insertions (3). The

mutations lead to defect at the level of transcription or translation or to change of individual amino acids in factor VIII protein (3, 4). At the present, more than 1209 mutations within the *F8* coding and un-translated regions have been identified and listed in the *F8* HAMSTeRS mutation database. The most recent update of the HAMSTeRS database (30 November, 2012) listed more than 357 small deletions, 255 large deletions and more than 146 insertions as being causative for Hemophilia A. The recurrent insertions or deletion of a single A has also been

reported at shorter stretches of A nucleotides (5, 6). Inversions cause about half of the cases of severe hemophilia A. Inversion mutation reported in intron 22 in 48 to 52% in intron 1 in 4-5% of patients with severe hemophilia A. The intron 22 of the FVIII gene contains a 9.5 kb region; int22h1, which is present outside of the gene (7). Insertions and deletions that cause HA are classified into large (more than 50 bp) and small which usually span one or several nucleotides. Various types of repetitive sequences, including SINES and LINES, which are present in the factor VIII gene, may be involved (8).

Currently, the Inv22 can be detected either by Southern blot analysis or by long-distance PCR (LD-PCR) (9). Given the shortcomings of these detection methods, a new system for Inv22 analysis can be IS-PCR that is used for Inv22 and Inv1 genotyping (10, 11). The main objective of this study was to genotype the coagulation factor VIII gene mutations using inverse-shifting PCR in an Iranian family with severe Haemophilia A.

Materials and Methods

Patients

In this experimental research, an Iranian family member with severe hemophilia A was chosen for investigation of Intron 22 and 1 Inversions of Factor VIII Gene. All participants provided written informed consent which was approved by the institutional review board before participation.

Genotyping

Five ml of peripheral blood was collected in tubes containing EDTA. Genomic DNA was extracted by commercial DNA extraction kit (Qiagen, Germany). Then quality and quantity of extracted DNA were assessed by nanodrop and agarose gel electrophoresis, respectively. Molecular analysis was performed using the following strategy. Patients with severe HA (FVIII: C < 1%) were first screened for intron 22 (Inv22) and intron 1 (Inv1) inversions using an Inverse Shifting

Polymerase chain reaction (IS-PCR) method. Mutations were compared to those previously described on the HAMSTeRS mutation register. Briefly, 2 µg of genomic DNA was digested with 20 units BclI enzyme (Fermentas, Canada) for 4 h in a 50 µl reaction buffer. Self-ligation of digested fragments was performed overnight at 15°C in a total volume of 400 µl with three units of T4 DNA Ligase (Fermentas, Canada). Fragmented DNA was extracted once in phenol-chloroform and once in chloroform-isoamyl alcohol (24:1 by volume), precipitated in 0.3 mol/L NaCl with 2 volumes of ethanol, and re-suspended in 30 µL of distilled water. PCR was performed in a volume of 25 µl containing 3 µl and 6 µl of circularized DNA for assessing Inv1 and Inv 22, respectively, 0.6 µM of each primer, 0.5 U of Taq DNA polymerase enzyme (Cinnagen, Iran), 200 µM dNTP, 1.5 mM MgCl₂, 10× PCR buffer with the following step: a denaturing at 94°C for 2 min, 32 cycle at; 94 °C for 30 s, 60 °C for 1 min, and 72 °C for 90s and a final extension step at 72°C for 5 min.. The IS-PCR products were then separated on a 2% agarose gel electrophoresis and visualized under UV light. The primers characteristics are given in Table 1. Exons amplification of the *F8* gene was done with a standard primer set of 37 primers related to regions of the *FVIII* (*F8*) gene under the same thermal cycling conditions. The primers for each PCR have a common tail to allow the use of one complementary sequencing primer in all forward sequencing reactions. PCR reactions for exon amplification region was performed under identical conditions: 95 °C for 2 minutes followed by 30 cycles of 94 °C for 30 S, 59 °C for 45 S and 72 °C for 90 S, and final extension at 72 C for 5 min. All PCR products were separated electrophoretically in 1% agarose gel.

Results

In this study, inversions in the *FVIII* (*F8*) gene intron 1 and 22 of prob and her

sister (Figure 1) by IS-PCR molecular diagnostic method. However, results showed that they were normal for introns 1 and 22 (Figure 2). Sequence analysis revealed a 2 bp AA deletion in exon 18 and a missense mutation in exon 14. These mutations were confirmed in patient's mother and sisters. The 2 bp AA deletion in exon 18 was a novel mutation that has not been reported yet. The mutation in exon 18 was a new mutation that has not

been reported yet. This mutation caused a stop codon after 87 nucleotides that mean the protein sequence terminated after 29 amino acids and produced an incomplete protein. In addition, the identified mutation in exon 14 was a missense mutation, C-to-G transition at position 3780 at the exon. Figure 3 and 4 show IS-PCR gel electrophoresis and figure 5 and 6 demonstrate the DNA sequence analysis of the exons.

Table I: The characteristic of primers used in this study

Primers	Sequence 5'-3'	Product size (bp)
Intron 1		
1-IU	GCCGATTGCTTATTTATATC	304
1-ID	TCTGCAACTGGTACTCATC	304
1-ED	GCCTTTACAATCCAACACT	244
Intron 22		
ID	ACATACGGTTTAGTCACAAGT	487
1U	CCTTTCAACTCCATCTCCAT	487
2U	ACGTGTCCTTTGGAGAAGTC	333
3U	CTCACATTGTGTTCTTGTAGTC	385

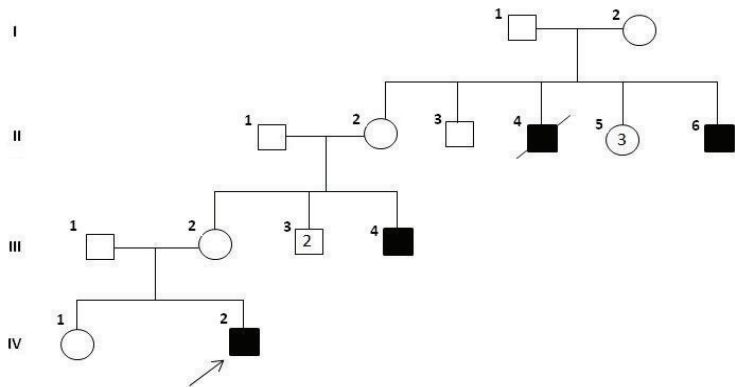


Figure 1. Pedigree of patient with severe Haemophilia A, his factor VIII clotting activity is lower than 1%.

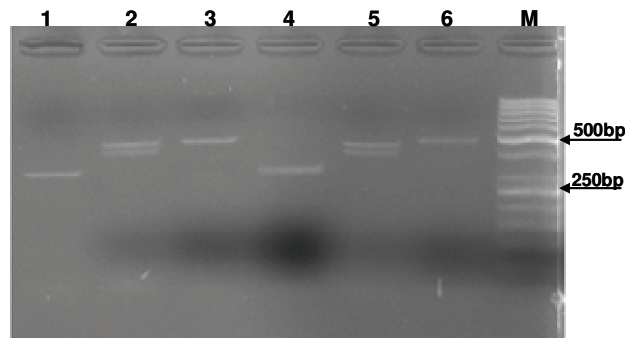


Figure 2. The IS-PCR products from a severe HA patient and his family using 1-ID and 1-IU primers. Line 4-6: Patient, Lines 1-3: Her sister; Line 1 and 4: Show 304bp band (1-ID and 1-IU primers) that indicate the normal band for intron 1 and 22. Line 2 and 5, 487bp band that is normal for both introns. Line 3 and 6 show a fragment of 457bp (2U and ED primer) and 405bp (ED and 3U), respectively that are normal for intron 22. Line 7: DNA ladder (50bp).

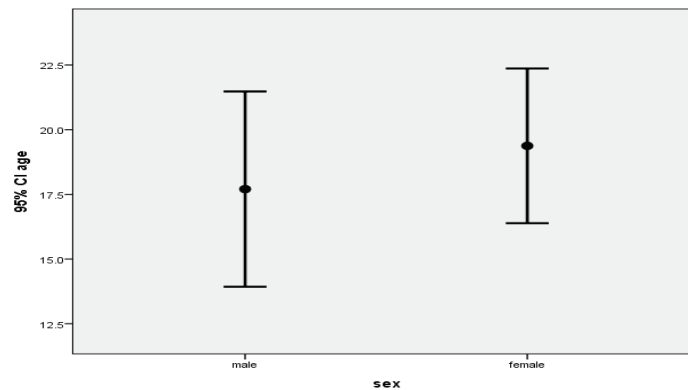


Figure 2. Average age according to sex (Error Bar Accordigto the confidence interval)

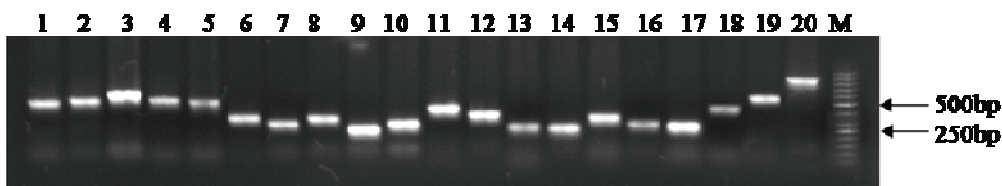


Figure 3. One percent agaros gel electrophoresis of PCR products. line 1-20 show exons 14E, 14D, 15C, 14B, 14A, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1 , promote 1 and promoter 2, respectively. The sizes of these exons are 570,595, 695, 599, 567, 364, 298, 361, 250, 300, 448, 400, 258, 259, 372, 299, 290, 480, 600, and 896 bp, respectively. In the last line loaded DNA ladder 50bp. The last line is DNA ladder 50bp.

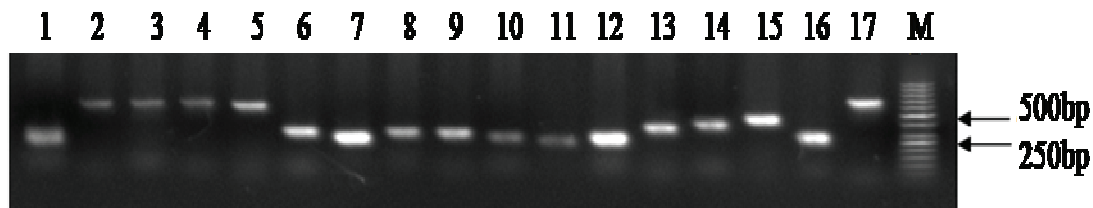


Figure 4. One percent agarose gel electrophoresis of PCR products. line 1-17 show exons 26E, 26D, 26C, 26B, 26A, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14F, respectively. The sizes of these exons are 230, 580, 580, 596, 557, 300, 250, 294, 287, 261, 228, 248, 262, 397, 468, 299, and 686 bp, respectively. The last line is DNA ladder 50bp.

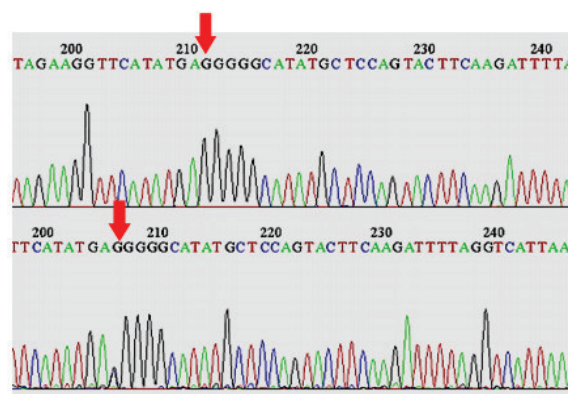


Figure 5. Exon 14 sequence analysis by reverse primer. A: patient. B: her mother. Red arrows show the mutation sites. The mother was heterozygote (c.3780C>G).

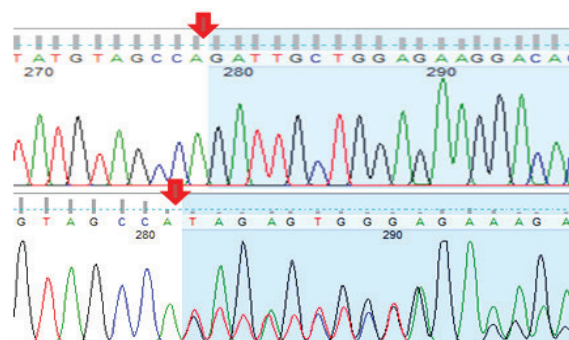


Figure 6. Exon 18 sequence analysis by reverse primer. A: patient. B: her sister. The red arrows show mutation location.

Discussion

The human *F8* gene was cloned during 1982–1984. However, the identification of the mutations, the causal agents of hemophilia was performed in 1993 years (10, 11). To date, wide diversity of practical approaches including Southern blot, distance PCR (LD-PCR), and inverse shifting-PCR have been used for genotyping the Inv22. LD-PCR permits the analysis of long sequences of DNA and can analyze the inversion, deletion, and translocation in the genome. Recently, IS-PCR method has been developed and applied for the detection of int 22 inversion in different studies. Therefore, the genome sequencing, southern blot analysis, LD-PCR, and IS-PCR techniques for Inv22 genotyping are interesting example of evolution in order to resolve challenging molecular diagnostic problems (10).

IS-PCR method can identify all DNA structural rearrangements related to intron 22 and intron 1 including large deletion, inversion, translocation, and duplication. In this study, IS-PCR assay was used to evaluate the presence of int 22 and int 1 inversions in severe HA patients family. Intron 22 inversions are estimated to be the cause of 40% of severe cases of hemophilia A (12-14). It seems that Intron 22 inversions occur at a 10 fold higher rate in male germ cells. Intron 22 contains 32 kilobases (kb) and is composed of two nested genes; namely, *F8A* and *F8B*. Furthermore, intron 22 contains a 9.5kb region which is also present outside of the *FVIII* gene, near two extragenic copies located 400kb 5' to the *FVIII* gene (15, 16).

Results of present study showed that the family members with HA were normal for introns 1 and 22. In addition, a new missense mutation at position 3780 exon 14 that caused Aspartic acid to Glutamic acid (Asp to Glu) was found. The second

mutation was a 2-bp deletion AA in exon 18 (nt. 5820-5823, del. AA). This deletion caused a frame shift in exon 18 and terminated after 29 amino acids for a premature stop codon. In this family, the proband's mother and sister were heterozygous for this deletion. In a study of 52 patients with unknown mutations, Traystman et al. (1990) Polymerase chain reaction technique and denaturing gradient gel electrophoresis (DGGE) was used to characterize single nucleotide substitutions in the exon 8, the 3-prime end of exon 14, exon 17, exon 18, and exon 24(16).) A deletion of a single nucleotide T within an A(8)TA(2) sequence of exon 14 of the *F8* gene was found In Japanese family with mild to moderately severe hemophilia A (17). They have observed that the severity of the clinical phenotype did not correspond to that expected of a frame shift mutation. An insertion of L1 elements into exon 14 of the *F8* gene in 2 of 240 Iranian unrelated patients with severe hemophilia A was detected (18).

The results of this study indicate that IS-PCR system is an ideal diagnostic tool for rapid genotyping of Inv 2 in *F8* gene. Fujita et al., (2012) have reported IS-PCR Inv22 diagnostic tests revealed that these patients carried either type I or II Inv22. However, they showed a wild-type (WT) pattern in the IS-PCR Inv22 complementary tests (19). In another study, 30 Iranian severe HA patients for the presence of intron 22 and intron 1 inversions at the *F8* gene were screened. Their results revealed that 47% of patients showed intron 22 inversion (40% type 1 and 7% type 2), while 7% of patients had intron 1 inversion. Among the patients carrying the inversion, 12% developed inhibitors (20). A total of 50 HA patients (including 35 non- Inv22, 14 Inv22-1, and one Inv22-2 patients) and 7 HA carriers were diagnosed by using modified inverse-shifting polymerase chain reaction and

capillary gel electrophoresis approaches which showed these methods could be considered as an ideal diagnostic tool for rapid genotyping of *Inv2* in *F8* gene (21).

Conclusion

Based on the obtained results, it can be concluded that two IS-PCR and genomic sequencing techniques are robust and low cost method that can facilitate the analysis of HA patients and carrier detection. In addition, a double mutation in the *FVIII* gene (*F8*) in an Iranian family with severe HA was found.

Acknowledgements

The authors have great thanks to all laboratory expert of Genetic Research Center of Meybod, Yazd, Iran.

Conflicts of Interest

All authors disclose any financial and personal relationships with other people or organizations and the authors declare that there is no potential conflict of interest.

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