

BJP

Bangladesh Journal of Pharmacology

Research Article

In silico prediction of functional loss
of *cst3* gene in hereditary cerebral
amyloid angiopathy

***In silico* prediction of functional loss of *cst3* gene in hereditary cerebral amyloid angiopathy**

Piyush Choudhary¹, Juhee Singh¹, V. Karthick¹, V. Shanthi¹, R. Rajasekaran² and K. Ramanathan¹

¹Industrial Biotechnology Division, ²Bioinformatics Division, School of Bio Sciences and Technology, Vellore Institute of Technology, Vellore 632014, Tamil Nadu, India.

Article Info

Received: 7 October 2013

Accepted: 23 November 2013

Available Online: 27 November 2013

DOI: 10.3329/bjp.v8i4.16524

Cite this article:

Choudhary P, Singh J, Karthick V, Shanthi V, Rajasekaran R, Ramanathan K. *In silico* prediction of functional loss of *cst3* gene in hereditary cerebral amyloid angiopathy. Bangladesh J Pharmacol. 2013; 8: 390-94.

Abstract

The computational identification of missense mutation in *CST3* (*CYSTATIN 3* or *CYSTATIN C*) gene has been done in the present study. The missense mutations in the *CST3* gene will leads to hereditary cerebral amyloid angiopathy. The initiation of the analysis was done with SIFT followed by POLYPHEN-2 and I-Mutant 2.0 using 24 variants of *CST3* gene of *Homo sapiens* which were derived from dbSNP. The analysis showed that 5 variants (Y60C, C123Y, L19P, Y88C, L94Q) were found to be less stable and damaging by SIFT, POLYPHEN-2 and I-MUTANT2.0. Furthermore the outputs of SNP & GO are collaborated with PHD-SNP (Predictor of Human Deleterious-Single Nucleotide Polymorphism) and PANTHER to predict 5 variants (Y60C, Y88C, C123Y, L19P, and L94Q) having clinical impact in causing the disease. These findings will be certainly helpful for the present medical practitioners for the treatment of cerebral amyloid angiopathy.

Introduction

Single nucleotide polymorphisms (SNPs) are the most abundant form of genetics variations in the human genome. Most of the SNPs in the human genome are present in the non-coding DNA consisting of 5' and 3' and translated regions (UTR) (Rajasekaran et al., 2007). The dbSNP is used for the same and it is a public domain archive (Sherry et al., 2001).

The gene, *CST3*, codes for human cystatin C, and has the same organization as the *CST1* gene for cystatin SN and the *CST2* gene for cystatin SA (Saitoh et al., 1989). It has been found to play a role in brain disorder example amyloid (a specific type of protein deposition) (Goate et al., 1991).

Analysis found that missense mutation in the *CST3* gene lead to a condition called hereditary cerebral amyloid angiopathy. This condition is characterised by stock and dementia which begins in mid adulthood.

CST3 gene is located from base pair 23, 608, 533 to base pair 23, 618, 684 on chromosome 20 (Saitoh et al., 1989). As far as presence scenario is concerned the discovery of deleterious SNPs is crucial task for pharmacogenomics and pharmacogenetics. We undertook this work basically to perform a computational analysis of *CST3* gene consisting of ns SNPs and identification of possible deleterious mutation. Out of the 24 SNPs, the most deleterious SNPs which are significant in causing disease are Y60C, C123Y, L19P, Y88C, and L94Q. These mutations can be a candidate of most concern in the disease hereditary cerebral amyloid angiopathy caused by *CST3* gene.

Materials and Methods

Dataset

db-SNP (<http://www.ncbi.nlm.nih.gov/SNP/>) is used to obtain the SNPs and their related protein sequence



for CST3 gene of *Homo sapiens* for the computational analysis. (Arnold et al., 2006). Every SNP consist of a unique ID, reference ID (rsIDs). Complete information about that SNP as well as the amino acid changes, their respective positions and corresponding accessions IDs are obtained by clicking on each rsIDs. Clicking on accessions ID delivers information regarding the protein encoded by the genes. Also we are thankful for the availability of numerous comprehensive and easy to use software packages and web-based services to detect the structures (Kumar et al., 2009).

Sequence homology based method (SIFT)-Analysis of functional effect of point's mutations

The damaging single amino acid polymorphism detected by the SIFT programme (Ng and Henikoff, 2003). The main concept behind this technique is mainly based on the evolutionary amino acid conservation with in protein families. The more the conserved positions are the more they are intolerant to substitution where as the vice versa is also true. Therefore, the results are deleterious or damaging when the changes occurs at well conserved positions. Protein sequence forms of queries are being submitted. SIFT works by using multiple sequence alignment information on a considered query sequence for the prediction (Capriotti et al., 2005) of tolerated as well as deleterious substitution for each position for the query sequence. The multistep SIFT process consist of a) protein database search for related sequences, b) sequence alignment build-up, c) probability scaling at every position from the alignment. The cut off value of tolerance index for SIFT program ≥ 0.5 . the tolerance index is inversely proportions to the impact of amino acid substitutions that is higher the tolerance index lesser the impact of substitution and lesser the tolerance index the higher the functional impact of amino acid substitution.

Structure and sequence based method-POLYPHEN2 (polymorphism phenotyping v2)

POLYPHEN2 is a physical and comparison based tool that shows the impact of amino acid substitution on the structure and function of human protein (Ramensky et al., 2002). The input is a protein sequence with mutational positions and two variants of amino acids. This is followed by PSIC scores calculations for both the variants and then the difference between two are computed. The greater the PSIC score difference the higher the functional impact of particular amino acid substitution.

Stability analysis- I-Mutant 2.0

It is a SVM based tools that is i.e, which is support vector machine based tool. I-Mutant2.0 leads to automatic protein stability change prediction which is caused by single point mutation (Capriotti et al., 2005). The initiations were done either by using protein structure or more precisely from the protein sequence.

The output is a free energy change value ($\Delta\Delta G$). Positive $\Delta\Delta G$ value infers that the protein being mutated is of higher stability and vice versa is also true.

SNPs & GO- (disease related mutations predictions)

SNPs tends for Single Nucleotide Polymorphism data base and GO is Gene Ontology. Like I-Mutant2.0 SNPs & GO (Calabrese et al., 2009) is also a support vector machine (SVM) which is based on the method to accurately predict the mutation related to disease from protein sequence. The input is the FASTA sequence of the whole protein, the output is based on the difference among the neutral and disease related variations of the protein sequence. The RI (reliability index) with value of greater than 5 depicts the disease related effect caused by mutation on the function of parent protein. The PHD SNP (Altschul et al., 1997) & PANTHER algorithms were also used in the display of output.

Results and Discussion

There are 24 missense mutation were found namely Y60C, P33L, V75M, V44M, M67K, A129T, Y88C, A72S, D113A, A2S, G30S, T98M, C123Y, T142A, L19P, L94Q, R71S, R71H, V17M, G3R, R96G, G38A, R79H, A25T. These mutations were retrieved from dbSNP (Smigiel-ski et al., 2000).

The mutations were one by one submitted in SIFT program for the tolerance index (Ng and Henikoff, 2003) check. Out of the 24 variants, 8 variants were found to be deleterious with a tolerance index score of ≥ 0.5 . The result has been depicted in Table I. It was observed that 4 out of 8 variants were highly deleterious with a tolerance index score of 0. One variant with a tolerance index of 0.01, one with 0.03, one with 0.04 and one with 0.05.

The POLYPHEN2 program (Ramensky et al., 2002) was used after SIFT with protein sequence having mutational position submitted as inputs, A PSIC score ≥ 0.950 were found to be probably damaging, A PSIC score of ≥ 0.5 were found to be possibly damaging and the rest were found to be benign (Table I).

Following the POLYPHEN2 was I-Mutant2 program for the analysis. The program tells about protein structure stability, out of 24 variants 22 variants were found to have less stability (Table I). The transformations that happened in the amino acids as a result of the missense mutations are Y60C (polar amino acid to a polar amino acid), P33L (non-polar amino acid to non-polar amino acid), V75M (non-polar amino acid to non-polar amino acid), V44M (non-polar amino acid to non-polar amino acid), M67K (non-polar amino acid to polar basic amino acid), A129T (non-polar amino acid to polar amino acid), Y88C (polar amino acid to polar amino acid), A72S (non-polar amino acid to polar amino acid),

Table I

List of nsSNP predicted as deleterious, damaging and less stable by SIFT, PolyPhen-2 and I-Mutant respectively

rsID	AA change	Tolerance index	PSIC SD	Prediction	Stability
rs377450166	Y60C	0.03	0.999	Probably damaging	Decrease
rs375692362	P33L	0.32	0.051	Benign	Decrease
rs373743268	V75M	0	1	Probably damaging	Increase
rs373213120	V44M	0.16	0.867	Possibly damaging	Decrease
rs373177867	M67K	0.92	0	Benign	Decrease
rs371605207	A129T	0.63	0.01	Benign	Decrease
rs371124032	Y88C	0	1	Probably damaging	Decrease
rs202145575	A72S	0.09	0.37	Benign	Decrease
rs201184716	D113A	0.38	0.607	Possibly damaging	Decrease
rs200984369	A2S	0	0.939	Possibly damaging	Decrease
rs200245337	G30S	0.72	0.01	Benign	Decrease
rs200037041	T98M	0.09	0.975	Probably damaging	Decrease
rs149051742	C123Y	0.05	1	Probably damaging	Decrease
rs141643699	T142A	0.45	0.002	Benign	Decrease
rs113550984	L19P	0.01	0.94	Possibly damaging	Increase
rs28939068	L94Q	0	0.988	Probably damaging	Decrease
rs11542364	R71S	0.44	1	Probably damaging	Decrease
rs11542360	R71H	0.1	0.999	Probably damaging	Decrease
rs11542359	V17M	0.1	0.63	Possibly damaging	Decrease
rs11542357	G3R	0.09	0.002	Benign	Decrease
rs11542355	R96G	0.16	1	Probably damaging	Decrease
rs11542354	G38A	0.2	0.243	Benign	Decrease
rs11542353	R79H	0.04	0.999	Probably damaging	Decrease
rs1064039	A25T	0.41	0.003	Benign	Decrease

Table II

List of nsSNP predicted as disease associated by SNP & GO server

rsID	AA change	SNP & GO prediction	Probability score	RI
rs377450166	Y60C	disease	0.73	5
rs375692362	P33L	neutral	0.048	9
rs373743268	V75M	neutral	0.416	2
rs373213120	V44M	neutral	0.021	10
rs373177867	M67K	neutral	0.145	7
rs371605207	A129T	neutral	0.072	9
rs371124032	Y88C	disease	0.835	7
rs202145575	A72S	neutral	0.107	8
rs201184716	D113A	neutral	0.033	9
rs200984369	A2S	neutral	0.015	10
rs200245337	G30S	neutral	0.037	9
rs200037041	T98M	neutral	0.056	9
rs149051742	C123Y	disease	0.9	8
rs141643699	T142A	neutral	0.012	10
rs113550984	L19P	disease	0.537	1
rs28939068	L94Q	disease	0.682	4
rs11542364	R71S	disease	0.56	1
rs11542360	R71H	neutral	0.357	3
rs11542359	V17M	neutral	0.054	9
rs11542357	G3R	neutral	0.009	10
rs11542355	R96G	disease	0.541	1
rs11542354	G38A	neutral	0.034	9
rs11542353	R79H	neutral	0.253	5
rs1064039	A25T	neutral	0.042	9

D113A (polar acidic amino acid to non-polar amino acid), A2S (non-polar amino acid to polar amino acid), G30S (non-polar amino acid to polar amino acid), T98M (polar amino acid to non-polar amino acid), C123Y (polar amino acid to polar amino acid), T142A (polar amino acid to non-polar amino acid), L19P (non-polar amino acid to non-polar amino acid), L94Q (non-polar amino acid to polar amino acid), R71S (polar basic amino acid to polar amino acid), R71H (polar basic amino acid to polar basic amino acid), V17M (non-polar amino acid to non-polar amino acid), G3R (non-polar amino acid to polar basic amino acid), R96G (polar basic amino acid to non-polar amino acid), G38A (non-polar amino acid to non-polar amino acid), R79H (polar basic amino acid to polar basic amino acid), A25T (non-polar amino acid to polar amino acid). It can be said that by preserving the physico chemical properties of amino acids may not necessarily result in mutations that are harmless.

Out of the 24 variants, 8 variants namely Y60C, C123Y, L19P, R79H, V75M, Y88C, A2S, L94Q were found to be deleterious and damaging by all the three programs that is SIFT, POLYPHEN 2 and I-Mutant2.0 (Capriotti et al., 2005). The SNPs and GO server predicted 7 variants as disease causing mutation (Table II), whereas PHD-SNP server predicted 12 variants to be disease related (Table III), and PANTHER predicted 11 variants as disease (Table IV). Finally combining the results of all

Table III

List of nsSNP predicted as disease associated by PHD-SNP server

rsID	AA change	PHD-SNP prediction	Probability score	RI
rs377450166	Y60C	Disease	0.962	9
rs375692362	P33L	Neutral	0.195	6
rs373743268	V75M	Disease	0.863	7
rs373213120	V44M	Neutral	0.148	7
rs373177867	M67K	Disease	0.625	3
rs371605207	A129T	Neutral	0.348	3
rs371124032	Y88C	Disease	0.991	10
rs202145575	A72S	Disease	0.509	0
rs201184716	D113A	Neutral	0.324	4
rs200984369	A2S	Neutral	0.132	7
rs200245337	G30S	Neutral	0.341	3
rs200037041	T98M	Neutral	0.499	0
rs149051742	C123Y	Disease	0.993	10
rs141643699	T142A	Neutral	0.03	9
rs113550984	L19P	Disease	0.954	9
rs28939068	L94Q	Disease	0.897	8
rs11542364	R71S	Disease	0.889	8
rs11542360	R71H	Disease	0.824	6
rs11542359	V17M	Neutral	0.427	1
rs11542357	G3R	Neutral	0.044	9
rs11542355	R96G	Disease	0.931	9
rs11542354	G38A	Neutral	0.365	3
rs11542353	R79H	Disease	0.718	4
rs1064039	A25T	Neutral	0.254	5

Table IV

List of nsSNP predicted as disease associated by PANTHER server

rsID	AA change	PANTHER prediction	Probability score	RI
rs377450166	Y60C	Disease	0.975	10
rs375692362	P33L	Disease	0.504	0
rs373743268	V75M	Disease	0.808	6
rs373213120	V44M	Neutral	0.294	4
rs373177867	M67K	Neutral	0.371	3
rs371605207	A129T	Neutral	0.391	2
rs371124032	Y88C	Disease	0.973	9
rs202145575	A72S	Neutral	0.365	3
rs201184716	D113A	Neutral	0.188	6
rs200984369	A2S	Neutral	0.038	9
rs200245337	G30S	Neutral	0.112	8
rs200037041	T98M	Neutral	0.392	2
rs149051742	C123Y	Disease	0.995	10
rs141643699	T142A	Neutral	0.189	6
rs113550984	L19P	Disease	0.734	5
rs28939068	L94Q	Disease	0.859	7
rs11542364	R71S	Disease	0.817	6
rs11542360	R71H	Disease	0.848	7
rs11542359	V17M	Neutral	0.352	3
rs11542357	G3R	Neutral	0.099	8
rs11542355	R96G	Disease	0.847	7
rs11542354	G38A	Neutral	0.23	5
rs11542353	R79H	Disease	0.628	3
rs1064039	A25T	Neutral	0.294	4

Table V

List of nsSNP predicted as disease associated by SNP & GO, PHD-SNP and PANTHER server

rsID	AA change	SNP & GO	PHD-SNP	PANTHER
rs377450166	Y60C	Disease	Disease	Disease
rs149051742	C123Y	Disease	Disease	Disease
rs113550984	L19P	Disease	Disease	Disease
rs371124032	Y88C	Disease	Disease	Disease
rs28939068	L94Q	Disease	Disease	Disease

the programs, 5 variants namely Y60C, Y88C, C123Y, L19P and L94Q were predicted to have functional effect on protein function and stability (Table V), and further these functionally significant variants were superimposed with native structure using PyMol (Figure 1).

Conclusion

We examined clinically important mutations in CST3 gene by means of different genomic algorithms. We certainly believe that this analysis will have immense importance in clinical management of cerebral amyloid angiopathy.

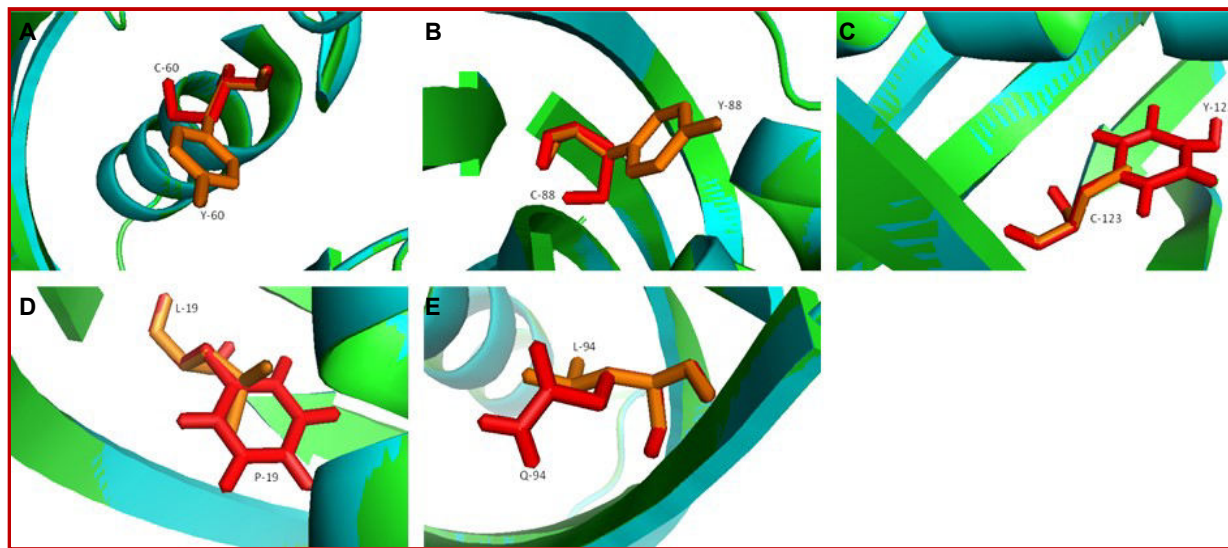


Figure 1: Superimposed view of C60Y (A), Y88C (B), C123Y(C), L19P (D) and L94Q (E) rendered using PyMol

Acknowledgement

The authors would like to thank management of VIT University for providing the facilities to carry out this work.

References

- Altschul SF, Madden TL, Schäffer AA, Zhang J, Zhang Z, Miller W, Lipman DJ. Gapped BLAST and PSI-BLAST: A new generation of protein database search programs. *Nucleic Acids Res.* 1997; 25: 3389-402.
- Arnold K, Bordoli L, Kopp J, Schwede T. The SWISS-MODEL Workspace: A web-based environment for protein structure homology modeling. *Bioinformatics* 2006; 22: 195-201.
- Calabrese R, Capriotti E, Fariselli P, Martelli PL, Casadio R. Functional annotations improve the predictive score of human disease-related mutations in proteins. *Human Mutation* 2009; 30: 1237-44.
- Capriotti E, Fariselli P, Casadio R. I-Mutant2.0: Predicting stability changes upon mutation from the protein sequence or structure. *Nucleic Acids Res.* 2005; 33: 306-10.
- Goate A, Chartier-Harlin MC, Mullan M, Brown J, Crawford F, Fidani L, Giuffra L, Haynes A, Irving N, James L, Mant R, Newton P, Rooke K, Roques P, Talbot C, Pericak-Vance M, Roses A, Williamson R, Rossor M, Owen M, Hardy J. Segregation of a missense mutation in the amyloid precursor protein gene with familial Alzheimer's disease. *Nature* 1991; 349: 704-06.
- Johansson MU, Zoete V, Michielin O, Guex N. Defining and searching for structural motifs using DeepView/Swiss-PdbViewer. *BMC Bioinformatics.* 2012; 13: 173.
- Kumar P, Henikoff S, Ng PC. Predicting the effects of coding non-synonymous variants on protein function using the SIFT algorithm. *Nat Protoc.* 2009; 4: 1073-81.
- Ng PC, Henikoff S. Predicting deleterious amino acid substitutions. *Genome Res.* 2001; 11: 863-74.
- Ng PC, Henikoff S. SIFT: Predicting amino acid changes that affect protein function. *Nucleic Acids Res.* 2003; 31: 3812-14.
- Rajasekaran R, Sudandiradoss C, Doss CG, Sethumadhavan R. Identification and *in silico* analysis of functional SNPs of the BRCA1 gene. *Genomics* 2007; 90: 447-52.
- Ramensky V, Bork P, Sunyaev S. Human non-synonymous SNPs: Server and survey. *Nucleic Acids Res.* 2002; 30: 3894-3900.
- Saitoh E, Sabatini LM, Eddy RL, Shows TB, Azen EA, Isemura S, Sanada K. The human cystatin C gene (CST3) is a member of the cystatin gene family which is localized on chromosome 20. *Biochem Biophys Res Commun.* 1989; 162: 1324-31.
- Sherry ST, Ward MH, Kholodov M, Baker J, Phan L, Smigielski EM, Sirotkin K. dbSNP: The NCBI database of genetic variation. *Nucleic Acids Res.* 2001; 29: 308-11.

Author Info

K. Ramanathan (Principal contact)
e-mail: kramanathan@vit.ac.in