Structure and Function Prediction of human homologue hABH5 of *E. coli* ALKB5 using *in silico* approach

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ABSTRACT

Newly discovered human homologues of ALKB protein have shown the activity of DNA damaging drugs, used for cancer therapy. Little is known about structure and function of hABH5, one of the members of this superfamily. Therefore, in present study we are intended to predict its structure and function using various bioinformatics tools. Modeling was done with modeller 9v7 to predict the 3D structure of the hABH5 protein. 3-D model of hABH5, ALKBH5.B99990005.pdb was predicted and evaluated. Validation result showed 96.8% residues in favored and additional allowed region of Ramachandran plot. Ligand binding residues prediction showed four ligand clusters, having 25 ligands in cluster 1. Importantly, conserved pattern of Pro158-X-Asp160-Xn-His266 in the functional domain was detected. DNA and RNA binding sites were also predicted in the model. The predicted and validated model of human homologue hABH5 resulted from this study may unveil the mechanism of DNA damage repair in human and accelerate the research on designing of appropriate inhibitors aiding in chemotherapy and cancer related diseases.

INTRODUCTION

Selective killing of cancerous cells through alkylating agents by DNA damage is an important approach to combat cancer. *Escherichia coli* AlkB and its human homologues (hABH) are recently discovered as alkylating agents involve in oxidative demethylation of 1-methyladenine and 3-methylcytosine which has expanded the concept of alkylation repair by direct reversal method (Mishina et al., 2006). These molecules play an active role in triggering cell's response to DNA damage. Earlier bioinformatics methods had been used to show the relatedness between the different human homologues of Alkb proteins (Kurowski et al., 2003) as well as for the theoretical investigations of structure and function of hABH1 (Shankaracharya et al., 2010a) and hABH4 (Shankaracharya et al., 2010b) proteins. It was also observed, in another study, that majority of the bacterial AlkB proteins are DNA repair enzymes, and some of these proteins do not primarily target methylated bases (Born et al., 2009).

Some ALKBH enzymes have been demonstrated to function as nucleic acid demethylases, catalyzing the oxidative demethylation of 1-methyladenine and 3-methylcytosine in DNA and RNA (Aravind et al., 2001; Ducan et al., 2002; Falnes et al., 2002). Eight human AlkB homologues (ALKBH1-8) have been predicted, of which three (ALKBH1-3) have been shown to exhibit nucleic acid demethylation activity (Kurowski et al., 2003; Falnes et al., 2002; Westbye et al., 2008). Additionally, a DNA lyase activity has been recently described for ALKBH1 that is Fe(II) and 2-Oxoglutarate (2OG) independent (Muller et al., 2009). Expression of ALKBH8 has been implicated in bladder cancer progression. Recently, a tRNA methyltransferase activity of ALKBH8 has been described and implicated in translational decoding (Fu et al., 2010; Shimada et al., 2009; Songe-Moller et al., 2010).

Recently it was reported that ALKBH5 was probably unique amongst the ALKBH genes in being a direct transcriptional target of hypoxia inducible factor-1 (HIF-1) and was induced by hypoxia in a range of cell types. Hence a new class of HIF-transcriptional target gene was found and suggested that ALKBH5 might have a role in the regulation of cellular responses to hypoxia (Thalhammer et al., 2011).

Need for 3D structure of the AlkB homologues in humans and their structural and functional characterization is significant in recent field of research in cancer medicine and cancer molecular biology. Therefore present study focuses on to the modeling of the 3D structures of hABH5 homologue in humans to understand the characteristic features and to predict its function. Moreover homologues related to cancer therapy if modeled would ease out a way to design inhibitors aiding in chemotherapy.

MATERIALS AND METHODS

Search and retrieval of target protein sequence

Information about protein sequence of human analogue of Alkb (hABH5) was retrieved from NCBI (http://www.ncbi.nlm.nih.gov/).

Selection of template

Template was selected by homology search of query protein (hABH5) sequence against the databases available on PDB (http://ww.rcsb.org) using mGenThreader (Jones, 1999) method. Using mGenThreader web server, templates were selected using fold assessment between target and template.

Homology modeling and evaluation of Model

Homology modeling was done using Modeller 9v7 (Fiser and Sali, 2003; Sali and Blundell, 1993). Difficult modeling was used as the identity between target and template sequences was less. This requires one sequence of known 3D structure and Python 2.5 script files containing Modeller commands. The co-ordinate file of template from PDB was used as such. The predicted model was validated with the program Procheck (Laskoswki et al., 1993) and Ramachandran plot statistics was used to evaluate the stability of the model.

Protein structure accession number

The refined homology model of 3D structure of Habh5 of human was submitted to PMDB (http://mi.caspur.it/PMDB/) (Castrignano et al., 2006) and the same was assigned the identifier PM0076285.

Function prediction

3d2GO server was used for prediction of functions of the predicted model using sequence and structure in the reference of Gene Ontology (GO). It predicts the function of the protein using sources of information like overall topological similarity to structures with known function, geometric and residue similarity of predicted functional sites to regions of known structures and sequence homology to functionally annotated sequences. Then all these information was processed by a Support Vector Machine trained to discriminate between true and false positive functional assignments (http://www.sbg.bio.ic.ac.uk/phyre/pfd/). MAMMOTH structural alignment program was used for full topology search of the model (Ortiz et al., 2002). MUSCLE program was used for functional site prediction of the predicted model (Edgar and Robert, 2004). Functional residue prediction was done using the Jenson-Shannon Divergence (JS Divergence), an information-theory approach to determine relative residue conservation (Capra and Singh, 2007). Such conservation is related to the functional importance of residues. After the finding of the functional site residues, the site was scanned against structures of known function using a fast geometric hashing technique (Moll and Kavraki, 2008).

3DLigandSite prediction

Protein ligand binding residues was predicted using program 3dLigandSite using Critical Assessment of protein Structure Prediction experiment (CASP) (Wass and Stemberg, 2009). This was based on an approach to identify binding sites by combining the use of the predicted structure of the targets with both residue conservation and the location of ligands bound to homologues structures.

RNA binding residue Prediction

RNA interface residue prediction from protein 3D structure was done with **KYG**, a 3D structure based prediction of RNA interface residues in a protein (Kim et al., 2006). It is available at http://cib.cf.ocha.ac.jp/KYG/ .

RESULTS AND DISCUSSION

Search for template on National Centre for Biotechnology Information has generated only few homologous structure hits of low identities. Hence difficult modeling method of modeller was used to model the 3D structure of hABH5. Human ABH3 (pdb id 2IUW) was selected as template using mGenThreader tool (Jones, 1999) on the basis of best NetScore (63.057) out of various other related parameters.

The protein sequences of target (hABH5) and template hABH3 (PDB ID- 2IUW) were aligned and the result of alignment is shown in figure 1. The asterisk showed the identity of amino acids present in two protein sequences.

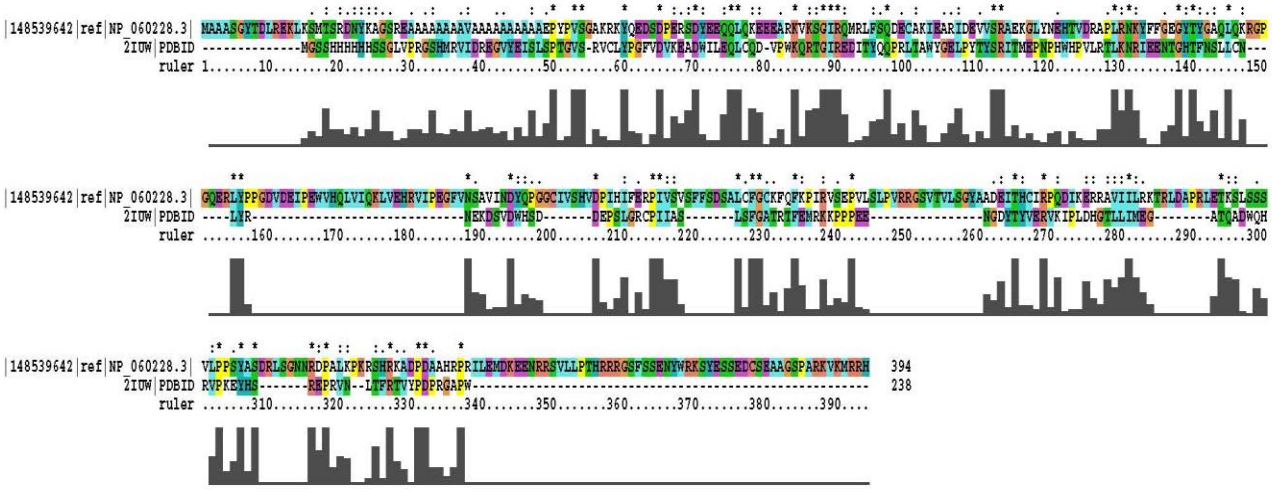

Figure 1: MSA result of hABH5 with the template sequence of 2IUW

Total 5 models were generated after performing homology modeling with modeller 9v7. Dope scores of the generated models were calculated using the command model-single.py. The model ALKBH5.B99990005.pdb, having minimum dope score was considered as the best model of protein hABH5 (Table 1). This result was also supported by the minimum Molpdf and GA341 scores among five models.

Table 1: Dope energy and related information about successfully produced models

Sl. No.	Filename	Molpdf	DOPE score	GA341 score
1	ALKBH5.B99990001.pdb	3175.66333	-19757.95508	0.00223
2	ALKBH5.B99990002.pdb	3186.67163	-19354.21680	0.00107
3	ALKBH5.B99990003.pdb	2666.46167	-20275.49219	0.00103
4	ALKBH5.B99990004.pdb	2927.02832	-18743.20703	0.00111
5	**ALKBH5.B99990005.pdb**	**2658.51123**	**-20798.55859**	**0.00101**

Further validation program, Procheck (Laskoswki et al., 1993) was used to perform full geometric analysis as well as stereochemical quality of a protein structure by analyzing residue-by-residue geometry and overall structure geometry. After running Procheck, Ramachandran plot (Figure 2) shows that for the model hABH5.B99990005, 89.6% residues were in favored region, 7.2% in the additional allowed region, 1.4% in the generously allowed region and 1.7% of the residues in the disallowed region, which made this model more acceptable as compared to other predicted models (Table 2). Homology modeling study is an important method to know the 3D structure of the protein whose structure is not available (Kurowski et al., 2003). Similar approach was also used in the prediction of 3D structure of vaccine related kinaase1 (vrk1)

protein (Shankaracharya et al., 2010c), Tubulin β-1 (Shankaracharya et al., 2010d), CDCP2 (Shankaracharya et al., 2010e) and cyclin dependent kinase 4 protein (CDK4) (Shankaracharya et al., 2010f) to predict the respective stable structures and their functionality.

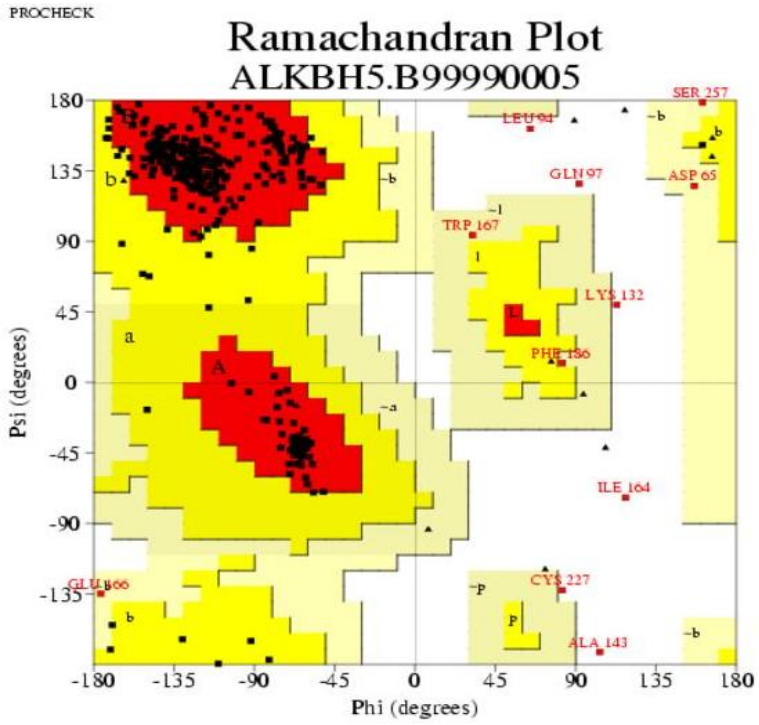

Figure 2: Ramachandran plot of the best model (**ALKBH5.B99990005.pdb**) predicted. Here out of total 347 residues present in the model, 311 lies in Most favored region, 25 in additionally allowed region, 5 in generously allowed region and 6 residues lie in disallowed region.

Table 2: Comparative analysis of Ramachandran Statistics in all the five predicted models

Predicted Structure	Ramachandran Statistics			
	No. of Residues in (%)			
	Most favored Region	**Additional allowed Region**	**Generously allowed Region**	**Disallowed region**
ALKBH5.B99990001.pdb	87.9	7.6	2.4	2.0
ALKBH5.B99990002.pdb	85.6	10.7	2.3	1.4
ALKBH5.B99990003.pdb	85.6	10.1	1.2	3.2
ALKBH5.B99990004.pdb	84.4	11.0	1.4	3.2
ALKBH5.B99990005.pdb	**89.6**	**7.2**	**1.4**	**1.7**

The 3d2GO server was used to predict the function of the protein model. This uses several methods of function prediction, using sequence and structure, to predict Gene Ontology (GO) terms for the protein. Various GO terms, their description and the confidence has been listed in Table 2. Confidence ranges from 0 to 1, with 1 being the most confident prediction. Result show that the predicted protein hABH5.B99990005.pdb has functions like ion binding, and Metal ion binding with good confidence (Table 3), which confirms the role of hABH5 as 2OG dependent oxygenase (Thalhammer et al., 2011) . Two functional sites were also predicted containing amino acid residues as ASP206, VAL248, PHE221, GLN196, GLY198, and THR254 in the first site and PHE228, ARG250, ARG249, GLY229, CYS227, ASN104 in the second. The residues present in the conserved cluster were predicted as PHE220, SER219, VAL218, LEU256, SER217 and PHE221.

Table 3: Result showing the function prediction of the modeled protein hABH5.B99990005.pdb with 3d2GO (Protein function prediction server)

Sl. No.	GO Term	Description	Confidence
1	GO:0043167	Ion binding	0.82
2	GO:0046872	Metal ion binding	0.71
3	GO:0046914	Transition metal ion binding	0.54
4	GO:0043169	Cation binding	0.52
5	GO:0005488	Binding	0.38
6	GO:0004175	Endopeptidase activity	0.37

3dLigandSite program was used for the prediction of protein ligand binding residues in Critical Assessment of protein Structure Prediction experiment (CASP). Further the tertiary model of the predicted protein was subjected to the slower but more sensitive structure alignment program MAtching Molecular Models Obtained from Theory (MAMMOTH). The result identified four ligand clusters; among them the first one is most significant predicting 25 ligands as well as 25 structures with average mamooth score of 11.5 (Table 4). In this cluster PRO158, ASP160 and HIS266 residues were predicted in the binding site whose numbers of contacts; average distance and JS divergence have been depicted in Table 5. JS divergence is measured in 0 to 1 scale and higher score mean more conserved residue. Hence the result shows that HIS266, PRO158 and ASP160 are more conserved residue in the structure. In the predicted ligand binding site, heterogens present in the ligand cluster 1 were predicted. The number of each type of ligand and the structures they originated from are also presented (Table 6). Previous study of three-dimensional model prediction for hABH1 active site residues based on other AlkB template

2FD8 has shown that hABH1 contains the five perfectly conserved amino acids in the AlkB family that constitute the iron and 2OG-binding motifs (Westbye et al., 2008).

Table 4: Different ligand clusters information shows that Cluster 1 has maximum numbers of ligands and structures (25 each) with the average Mammoth score of 11.5

Cluster	Ligands	Structures	MAMMOTH Scores		
			Av	Min	max
1	**25**	**25**	**11.5**	**7.9**	**24.5**
2	2	2	8.2	8.1	8.4
3	1	1	24.5	24.5	24.5
4	1	1	24.5	24.5	24.5

Table 5: List of amino acid residues observed in cluster 1 of predicted protein with number of contacts of ligand, Average distance and JS divergence

Residue	Amino acid	Contact	Av distance	JS divergence
158	**PRO**	20	0.21	0.26
160	**ASP**	24	0.00	0.19
266	**HIS**	25	0.00	0.78

Table 6: No. of Counts and list of Heterogens present in the predicted binding site

Heterogen	Count	Source structures
NI	1	3bkq_A
MG	1	3btx_A
FE	4	2iuw_A, 2rdr_A, 1blz_A, 2rdq_A
FE2	**18**	**3i49_A,2fdg_A,2fd8_A,3i2o_A,2fdi_A, 2fdk_A,2fdj_A,2g1m_A, 3hqu_A,2g19_A,3gjb_B,2hbt_A,2alx_A,2vcm_A,2hbu_A,1 odm_A,1obn_A,1hb4_A,1hb3_A**

KYG was used to predict the RNA interface residues on a protein surface (Wass and Sternberg, 2009). The method is based on propensity of residue occurrence in the interface of protein and RNA molecules observed in protein-RNA complex structures. The result shows that residues P354, T355, H356, R357, R358, R359, G360 and S361 are present at the interface of RNA and protein molecule. Further DNABindR (Yan et al., 2006) server was used to analyze and predict the DNA binding sites in proteins. Two overlapping clusters were detected ranging from position 320 to 327 and 383 to 393 respectively. The similar Structure and function prediction strategies were also used for the other human homologue of alkb proteins. For hABH1, it was found that H231, H287 and D233 were more conserved residue in the structure. The result has also depicted residues R24, K25, F27, R28, Y30, R31, Q32, S33, R34, P35 and G36 at the RNA binding site of the predicted protein molecule (Shankaracharya et al., 2010a).

Therefore, the model developed through homology modeling and subsequently the predicted functional characteristics of hABH5 will initiate the research on identifying a suitable mechanism of repair of alkylation damaged DNA and thus, provide better control on cancer treatment as these DNA repair systems are essential for the maintenance of genome integrity. Consequently, the deregulation of repair genes can be expected to be associated with significant, detrimental health effects, which can include an increased prevalence of birth defects, an enhancement of cancer risk, and an accelerated rate of aging.

CONCLUSION AND PROSPECTS

Homology modeling and function prediction study of hABH5 was performed. The predicted model was validated with program Procheck which shows 96.8% residues in allowed and additionally allowed regions. The ion binding and metal ion binding were predicted as important functional site of the model with high confidence. HIS266, PRO158 and ASP160 were found as more conserved residue in the structure. Further the result also depicted residues P354, T355, H356, R357, R358, R359, G360 and S361 at the RNA binding site of the protein molecule. These findings are the subject to experimental verification and application for the finding of new chemotherapeutic agent to combat cancer.

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