Functional Recombinant Extra Membrane Loop of Human CD20, an Alternative of the Full Length CD20 Antigen

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ABSTRACT

Background: Targeting of CD20 antigen with monoclonal antibodies has become the mainstay in the treatment of non-Hodgkin's lymphomas and immunotherapeutic depletion of malignant B cells. Accessibility of antigen is one of the crucial factors in development of monoclonal antibodies against this antigen. One major problem in expression of full length CD20 is aggregation and misfolding. Therefore, production of an alternative polypeptide is easier and favorable comparing to that of a full length transmembrane protein CD20.

Methods: In this study, we expressed the extra membrane loop of hCD20 (exCD20) consisting of a non-glycosylated 47-amino acids region. The exCD20 coding sequence was amplified by PCR and cloned in pET32a(+) expression vector. The desired protein was expressed in fusion with thioredoxin and 6× His tag in E. coli Origami strain. ELISA and Western-blotting data were performed to indicate the functionality of this protein.

Results: We have obtained the exCD20 recombinant protein which can be detected in ELISA and Western-blot experiments. This recombinant fusion protein was soluble and stable without aggregation and misfolding problems.

Conclusion: The recombinant extra membrane loop of human CD20 protein in fusion with thioredoxin (exCD20) can be used in function assays and some applications such as ELISA, immuneblotting, affinity purification, immunization, screening, and development of anti-CD20 antibodies.

Keywords: E. Coli, CD20, Thioredoxin

INTRODUCTION

World Health Organization has reported that 7.6 million people worldwide died from cancer in 2008. The Non-Hodgkin's lymphoma is expected to be the fifth most common cancer in American men and women [1]. It is a disease in which malignant (cancer) cells are formed in the lymph system. For lymphomas, chemotherapy and radiation therapy have been the mainstay of treatment. On the contrary of immunotherapy, both of these modalities suffer from a lack of specificity [2].

All the currently available anti-CD20 antibodies have been selected and produced against the extra membrane loop of hCD20 via different immunization methods [3]. The human B-lymphocyte-restricted differentiation antigen Bp35 (CD20, MS4A1), a 35-kDa hydrophobic phosphor-protein, is expressed as a cell surface, non-glycosylated protein during early pre-B-cell development [4] and predicted to span the plasma membrane four times. It is highly expressed on the plasma membrane of almost all plasma B cells, but not on hematological stem cells [5] and plasma cells [6]. This 297 amino acid length protein is consisted of cytoplasmic N- and C-termini and four hydrophobic regions for anchoring the molecule in the membrane. Although the biological function of CD20 remains unclear, some evidence indicated that it might function as a calcium ion channel [7-11]. The importance of CD20 as a target for immunotherapeutic depletion of B cells is irrefutable and anti-CD20 monoclonal antibodies appear to be ideal for the treatment of B-cell malignancies [12].

While for many soluble proteins suitable overexpression systems are used routinely, high-level production of membrane proteins is still challenging.
One phenomenon frequently observed in *E. coli* is that many heterologous proteins become incorrectly folded and accumulate in the cytoplasm as insoluble aggregates, called inclusion bodies [13, 14]. Therefore, expression of full length hCD20 protein produces a recombinant protein with incorrect folding and/or probably aggregated forms and using some techniques like liposome technology for hCD20 antigen (Abnova, Taiwan) has not proved yet.

Up to now, a few other studies have focused on expression of full length hCD20 protein in different forms such as purified recombinant protein on the surface of a mammalian cell membrane or transmembrane domain of CD20 in fusion with gIII protein of a phage [15-18]. Misfolding, aggregation and hyper immunogenicity and complexity of fused protein/particle to the recombinant CD20 are the drawbacks that should be avoided.

In this study, we selected the 47 amino acid-extra membrane loops of hCD20 between the third and fourth transmembrane regions [19] to express it in membrane loops of hCD20 between the third and fourth transmembrane domain of CD20 in fusion with gIII protein of a phage [15-18]. Misfolding, aggregation and hyper immunogenicity and complexity of fused protein/particle to the recombinant CD20 are the drawbacks that should be avoided.

In this study, we selected the 47 amino acid-extra membrane loops of hCD20 between the third and fourth transmembrane regions [19] to express it in fusion with thioredoxin of pET32a(+) prokaryotic expression vector. After expression, it would be possible to assess the functionality of recombinant exCD20 by ELISA and Western blotting. The functional exCD20 may be used in some functional assays and applications, such as ELISA, immune blotting, affinity purification, immunization, screening, and development of anti-CD20 antibodies.

**MATERIALS AND METHODS**

**Cloning and construction of exCD20 expression cassette.** Amplification of exCD20 coding sequence was performed by PCR with 53°C of annealing temperature and using specific primers and the pORF9-hCD20a eukaryotic plasmid (InvivoGen, USA) as template. This vector is an expression vector containing the full length of human CD20a (MS4A1) isoform I gene. Cloning was facilitated by BamHI and XhoI restriction enzyme sites engineered in the primers used for amplification (underlined): tCD20F: TGGATCCATATGCTGTAACAGTA and tCD20R: AATCTCGAGTTATATGCTGTAACAGTA TTGG. The purified PCR product was ligated to pTZ57R/T plasmid (Thermo Scientific, USA) and used to Transform *E. coli* TOP10 strain competent cells by Top 10 strain competent cells by Transform *E. coli* TOP10 strain competent cells by *E. coli* Origami™ strain was used to inoculate 300 ml TB medium supplemented with 300 μl 1,000× ampicillin stock (100 μg/ml ampicillin final concentration) in a baffled shaker flask. The flask was incubated at 37°C at 200 rpm reaching optical density (OD_{600}) of 0.6 to 0.9 in an incubator shaker. Expression was induced by adding 0.5 mM isopropyl-beta-D-thiogalactopyranoside (Applichem, Germany). Induction was followed by 5 hours of incubation at 30°C and 200 rpm. *E. coli* cells were harvested by centrifugation at 5,000 ×g at 4°C for 8 min. The cell pellet was resuspended in 10 ml lysis buffer (50 mM Tris-HCl, pH 8.0), 25% w/v sucrose (Merck, Germany), 1 mM EDTA (Sigma, Germany), 100 μg/ml lysozyme (Sigma, Germany), and 1 ml complete protease inhibitor cocktail (Roche, Germany) in a 50 ml falcon tube and incubated on ice for 30 min. Then, it was frozen at -20°C and thawed by immersing the tube in 37°C water. Ten ml of the lysis buffer was added to the lysate and centrifuged at 8,000 ×g at 4°C for 8 min. Supernatant was collected and the expressed protein was purified by HisPur™ Ni-NTA Resin (Thermo Scientific, USA) via its 6× His tag. Imidazole removal and complementary purification of exCD20 protein was performed by size exclusion chromatography (SEC) by AKTA Explorer FPLC system (GE Healthcare Life Sciences, UK) and two separated peaks were fractionated.

**Characterization of exCD20:**

**ELISA tests.** ELISA plates (Nunc, Germany) were coated with 1 μg per well of exCD20 in PBS at 4°C overnight. Then, they were blocked with 2.5% BSA at 37°C for 2 h. After 3 washes, 100 μl of anti-CD20 peptide antibody in PBS (10 μg/ml) [20] was added to the wells and the plates were incubated at 37°C for 1.5 h. The wells were washed, and 100 μl of 1:4,000 diluted horseradish peroxidase-conjugated rabbit anti-mouse Ig (Sigma, Germany) was added, then incubated for 1.5 h at 37°C. After 5 washes, 100 μl of tetramethylbenzidine solution (Sigma, Germany) was added, the plates were incubated at room temperature in dark, then the reaction was stopped after 1 min. P5 peptide (the complete extra membrane loop of hCD20 with a disulfide bond between C_{167} and C_{183}) was fused to the 109aa TRX•Tag™ thioredoxin protein and 6× His tag.
Table 1. Nucleotide sequence of a gene coding for extra-membrane loop of human CD20 and its amino acid sequence. A 225-amino acid sequence was produced by expression of exCD20 pET32a recombinant vector.

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Sequence</th>
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| extra-membrane loop of hCD20 | Nucleotide | 141 bp  
AATATTAAAAATTCATTTTTTAAAAATGGAGAGTCTGAATTTTATTA  
GAGCTCACAACCATATATATATACATATACCTCACAACACCTGG   
CCTCTGAGAAAATCCCTCCATCTACATACACAGTACA             |
|                           | Amino acid | 47 aa  
NIKISHFLKMESLNFIRAHTPYINIYNECPANPSEKNSPSTQYCYSI  
EGDIHMSDKIIHLTDSDFTDVLKAGDAILVDFWAEWCGBPCKMIAPILDEI  
ADEYQGKLTVKLNIDQNPPTAPKYGRGPTLLFKNEGVAATKVGALES  
KQGQLKEFEDLANLGGSGHMMHHHHHHHHLVSQPGSKMKEAAKFERQ  
HMDSPDLGTDDDKAMADIGSNKISHFLKMESLNFIRAHTPYINIYNECPANPSEKNSPSTQYCYSI |
| Recombinant exCD20         | Amino acid | 225 aa  
EGDIHMSDKIIHLTDSDFTDVLKAGDAILVDFWAEWCGBPCKMIAPILDEI  
ADEYQGKLTVKLNIDQNPPTAPKYGRGPTLLFKNEGVAATKVGALES  
KQGQLKEFEDLANLGGSGHMMHHHHHHHHLVSQPGSKMKEAAKFERQ  
HMDSPDLGTDDDKAMADIGSNKISHFLKMESLNFIRAHTPYINIYNECPANPSEKNSPSTQYCYSI |

synthesized (Biomatik, Canada) and used as positive control. Lysate of E. coli Origami strain transformed by empty vector pET32a(+) (TRX), as well as PBS were used as negative controls. OD was measured at 450 nm by ELISA reader (State Fax 2100, USA). All procedures were performed in triplicate.

**SDS-PAGE and Western-blot analysis.** One microgram of each two peaks of SEC experiment (Fig. 2) was run on 10% NuPAGE® Novex Bis-Tris Mini Gels (Invitrogen, USA). The separated proteins were transferred to Hybond-C nitrocellulose membrane (GE Healthcare, UK) by using a Bio-Rad protein transfer apparatus (100 v, 250 mA, 90 min). PageRuler™ Prestained Protein Ladder (Thermo Scientific, USA) was used in both experiments. Following protein transfer, the nitrocellulose membrane was blocked by blocking buffer containing 5% skimmed milk plus 0.25% Tween. The exCD20 band was detected by the anti-CD20 peptide antibody (10 µg/ml in the blocking buffer, 1 h, 25°C), and alkaline phosphatase-conjugated anti-mouse antibody (Sigma, Germany) (1:2,000 dilution in the blocking buffer, 25°C, 1 h) as primary and secondary antibodies, respectively. Alkaline phosphatase enzyme conjugate was detected by nitro-blue tetrazolium chloride and 5-bromo-4-chloro-3-indolyphosphate p-toluidine salt substrates (Thermo Scientific Pierce, USA).

**RESULTS**

**Cloning and construction of exCD20 expression cassette.** In order to construct the exCD20 expression cassette, the 141-nucleotide sequence (47 amino acids) of the extra membrane loop of hCD20 (Table 1) was amplified by PCR and using tCD20F and tCD20R amplification primers. Amplified region gave a band of the expected size (around 150 bp) on a 1.5% agarose gel (Fig. 1A). The PCR product was cleaned up and after digestion with restriction enzymes, cloned into the pTZ57R/T and then subcloned into the pET32a(+) expression vector. The band of around 720 bp was corresponding to the PCR product of colony PCR with T7 Promoter and tCD20R primers (Fig. 1B). The positive clone was sequenced (Genfanavar, Iran) using tCD20F and tCD20R primers. The sequencing data was compared with sequence of hCD20 gene in the NCBI website (Gene ID: 931) and the sequence of inserted exCD20 was confirmed.

**Expression, purification and characterization of exCD20.** After Transformation of recombinant vector into E. coli Origami™, it was cultivated and induced with isopropyl-beta-D-thiogalactopyranoside. The expressed protein was a 225-amino acid sequence including the extra membrane loop of hCD20 peptide...
In the present study, we obtained a novel recombinant extra membrane loop of hCD20 in fusion with thioredoxin and its native disulfide bridge (exCD20).

Since 1988, a few studies have attempted to express recombinant hCD20 antigen for different purposes [15-18]. In one study, the full length of hCD20 was cloned and expressed [18]. However, aggregation, misfolding and inclusion body formation are common phenomena in expression of full length transmembrane proteins because of hydrophobic regions (membrane-spanning domains) within these types of proteins. In another study [17], a recombinant vector with full length of hCD20 was transfected into a mammalian cell line and CD20 was expressed on the surface of the cells in order to study the structure and function of CD20. Also, in a study [16], the extra-membrane loop of hCD20 has been displayed on the surface of M13K07 phage and this recombinant phage was used to develop immune response in animal. In this approach, most of the antibodies were developed against the phage but not the fused peptide, because the phage is a complex and strong immunogenic carrier. In addition, the native disulfide bond of hCD20 does not construct in the normal cytosolic condition in the bacteria as good as engineered strain like E. coli Origami host strain [21].

Since all the currently available anti-CD20 antibodies have been selected and produced against the extra membrane loop of hCD20 [3], in our study, we...

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<th>Sample</th>
<th>Mean of optical density (OD&lt;sub&gt;450nm&lt;/sub&gt;)</th>
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<tbody>
<tr>
<td></td>
<td>With antigen</td>
</tr>
<tr>
<td>exCD20</td>
<td>3.40</td>
</tr>
<tr>
<td>P5 peptide</td>
<td>2.98</td>
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<tr>
<td>TRX</td>
<td>0.17</td>
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<td>PBS</td>
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Table 2. ELISA results. One µg of the exCD20, P5 peptide or lysate of E. coli Origami strain which transformed by empty vector pET32a(+) (TRX), were coated in each well. The anti-CD20 peptide antibody and anti-mouse alkaline phosphatase-conjugated antibody were used as primary and secondary antibodies, respectively. ELISA test was performed in triplicate.
used the extra membrane loop of hCD20 instead of its full length. This region was expressed in a Thioredoxin fusion system in the E. coli Origami strain to force the formation of disulfide ridge [21] between its two cysteines in the cytosol as native form on the surface of B-cells [22]. This strategy resulted in a stable, soluble and functional protein [23, 24].

As Table 2 shows, in ELISA a high OD450nm value for exCD20 as well as P5 peptide were obtained. This result confirmed that exCD20 had an epitope with appropriate conformation to interact with the anti-CD20 peptide antibody. Western-blotting also confirmed this conclusion (Fig. 3).

Two bands of peak 1 and one band of peak 2 were detected in Western-blot experiment. The bands of about 30 kDa are corresponding to the exCD20 fused with the thioredoxin and His tags and the band of about 60 kDa seems to correspond to its dimer form (Fig. 3).

Purification steps show the necessity of optimization of conditions for purification of exCD20 with Ni-NTA column. Some changes in concentration of imidazole in the washing step, the volume of washing buffer and the time of binding incubation may reduce the contaminations and increase the xCD20purity.

The anti-CD20 peptide antibody which was developed against P5 peptide [20], detected the 30 kDa-band exCD20 in the Western-blot. The 60 kDa-band seems to be the exCD20 dimer (Fig. 3).

In conclusion, the functional exCD20 protein can be expressed in E. coli Origami host strain. This recombinant extra membrane loop of hCD20 can be used instead of its full length protein without aggregation and misfolding problems in development of poly- and/or monoclonal anti-hCD20 antibodies. Also, it may be used in ELISA, immunoblotting, affinity purification, immunization and screening.

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