Haplotype of gene Nedd4 binding protein 2 associated with sporadic nasopharyngeal carcinoma in the Southern Chinese population

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Abstract

Background: Bcl-3 as an oncoprotein is overexpressed in nasopharyngeal carcinoma (NPC). Nedd4 binding protein 2 (N4BP2), which is located in the NPC susceptibility locus, is a Bcl-3 binding protein. This study is aimed to explore the association between N4BP2 genetic polymorphism and the risk of NPC.

Methods: We performed a hospital-based case-control study, including 531 sporadic NPC and 480 cancer-free control subjects from southern China. PCR-sequencing was carried out on Exons, promoter region and nearby introns of the N4BP2 gene. The expression pattern of N4BP2 and Bcl-3 was also analyzed.

Results: We observed a statistically significant difference in haplotype blocks ATTA and GTTG between cases and controls. In addition, three novel SNPs were identified, two of which were in exons (loc132-e3l-snp2, position 39868005, A/G, Met171Val; RS17511668-SNP2, position 39926432, G/A, Glu118Lys), and one was in the intron6 (RS794001-SNP1, position 39944127, T/G). Moreover, N4BP2 was at higher levels in a majority of tumor tissues examined, relative to paired normal tissues.

Conclusion: These data suggest that haplotype blocks ATTA and GTTG of N4BP2 is correlation with the risk of sporadic nasopharyngeal carcinoma in the Southern Chinese population and N4BP2 has a potential role in the development of NPC.

Background

Bcl-3 was originally identified as expressed in chronic B cell lymphocytic leukemia [1]. Many cell growth and survival promoters can induce Bcl-3 expression, and Bcl-3 overexpression has been detected in other cancers such as nasopharyngeal carcinoma (NPC) [2,3]. Nedd4 binding protein 2 (N4BP2, GenBank:AY267013) is a Bcl-3 binding protein, N4BP2 protein contains a polynucleotide kinase domain (PNK) at the N-terminus and a Small MutS Related (Smr) domain with nicking endonuclease activity near C-terminus [3]. MutS is central to the DNA mismatch repair (MMR) systems that are responsible for maintain-
ing genome stability and protecting against mutation. Mutations in these genes are linked to the development of certain types of cancer [4,5]. Since N4BP2 contains a MutS-related domain, N4BP2 may play a role in MMR.

NPC is an epithelial tumor with an exceptionally high incidence in southern China, particularly in the Guangdong province [6,7]. Etiological and epidemiological studies have suggested that susceptibility genes may determine the predisposition to developing NPC [8,9]. Previously, we reported the use of 382 polymorphic microsatellite markers to identify a candidate susceptibility locus that mapped to chromosome 4p15.1-q12 (D4S2950-D4S2916) in a subset of NPC families [10]. Further analysis identified SNPs within or near this region, strongly suggesting the presence of an NPC susceptibility locus adjacent to the LOC344967 [11], very close to the N4BP2 gene.

We thus hypothesized that SNPs or other variation in the N4BP2 gene lead to a predisposition to developing NPC. We further hypothesized that the N4BP2 gene plays a role in tumorigenesis. To address these hypotheses, we examined N4BP2 haplotypes among NPC patients from southern China. We also examined mRNA levels of Bcl-3 and N4BP2 in NPC cell lines and tissues.

**Methods**

**Subjects**

A total of 531 sporadic NPC patients and 480 unrelated age, sex-, and geographically-matched healthy individuals from southern China were used for our case-control study. NPC patients were recruited from Sun Yat-sen University Cancer Center and the presence of differentiated non-keratinizing NPC or undifferentiated NPC was confirmed by histological analysis. Control subjects were recruited from the People’s Hospital of Guangdong Province. The characteristics of cases and controls are shown in Table 1. Although the incidence of NPC is generally higher among males than females, no significant difference in sex distribution existed between case and control groups in this study. The average age in the control group was 37 ± 10, and in the case group was 40 ± 10; thus the age distribution here is a good representation of the broader NPC patient population given that NPC incidence peaks at the relatively young age of 45.

**DNA preparation**

Genomic DNA was extracted from 5–10 ml peripheral blood using the QIAamp DNA Blood Midi kit (Qiagen, German).

**Primer design**

Between 250 and 400 bp of sequence surrounding SNPs sites were submitted to the primer design program [12]. The primers used for SNPs are shown in Table 2.

**PCR Amplification**

Long-distance PCR was performed in a total volume of 15 μl containing 200 ng of genomic DNA, 1.5 μl 10× Buffer, 50 μM dNTPs, 0.3 μM each primer, and 1 U Taq DNA polymerase. Samples were amplified with each pair of

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**Table 1: Profile of the study subjects**

| Characteristic       | Control (n = 480) | Case (n = 531) | Chi square | p |
|----------------------|-------------------|----------------|------------|---|
| Gender (Male/Female) | 354/126           | 390/141        | 0.01       | 0.91 |
| Age                  | 37 ± 10           | 40 ± 10        | 0.86       | 0.44 |

*p value obtained from Chi-square Test*

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**Table 2: Primers used for SNPs**

| Number | RefSNP(RS) (NCBI) | Forward primers(5′→3′) | Reverse primer(5′→3′) | Product size (bp) |
|--------|------------------|------------------------|-----------------------|-------------------|
| SNP1   | RS17439810       | agtggcagcttgctgcctct   | ggtcaacatgatgcctcct  | 257               |
| SNP2   | loc121-e3l-snp2a |                         |                       |                   |
| SNP3   | RS17511578       | ctttccgcttgctgcctcc   |                       |                   |
| SNP4   | RS17585937       | acatggcgcacagaggtg    |                       |                   |
| SNP6   | RS17511668-SNP2b | TCTGTTCAATGGAAAAATCCCA |                       |                   |
| SNP7   | RS794001-SNP1c   | GTCTCATATATGCGAAGCATCA |                       |                   |
| SNP9   | RS22523252       | agTGACGCTAATACACCTCA  |                       |                   |
| SNP10  | RS2271395        | tccattgcctcaaatgtttgga |                       |                   |
| SNP11  | RS1442855        | TCATTGGCTGACGTGTTCA   |                       |                   |
| SNP12  | RS2347044        | TCCGTGTTGAAAATGTGAAATGC |                       |                   |

*a Primers for loc121-e3l-snp2 are same as RS17439810.
*b Primers for RS17511668-SNP2 are same as RS17511668
*c RS794001-SNP1 are same as RS794001.
primers described above as follows: 94°C for 3 min, 10 cycles of 94°C for 30 s, 63°C for 1 min, and 72°C for 1 min; 25 cycles of 94°C for 30 s, 58°C for 1 min, 72°C for 1 min, and a final extension at 72°C for 7 min. First-round PCR products were diluted 5-fold for the second-round of PCR. Round 2 PCR conditions were 94°C for 3 min, 10 cycles at 94°C for 30 s, 65°C for 1 min, and 72°C for 1 min; 30 cycles at 94°C for 30 s, 62°C for 1 min, and 72°C for 1 min, and 72°C for 7 min. PCR products were visualized on a 1.2% agarose gel, stained with ethidium bromide, and visualized by a transilluminator.

**Genotyping**

PCR products were sequence using ABI377 or ABI3730 sequencers (PE Applied biosystem). Base calling, contig assembly contigs, and mutation detection was performed using Polyphred package (Polyphred, Phred/Phrap/Consed) [13]. All traces were visually inspected by at least two observers.

**Statistical methods**

Unrelated control samples were selected for analysis using the Hardy-Weinberg Equilibrium (HWE) test using an exact test. Standard EM algorithm was used to infer haplotype and estimate population frequency. Single marker and haplotype association test and significance estimation were performed using a permutation test.

**Cell Culture and Treatment**

NP69 (an SV40 large T antigen-immortalized nasopharyngeal epithelial cell line) and NP69-LMP1 (NP69 cells transfected with the LMP1 gene) were cultured in Keratinocyte-SFM medium (GibcoBRL) with Bovine Pituitary Extract and rEGF. C666-1 (a poorly differentiated nasopharyngeal epithelial cell line) was grown in RPMI 1640 supplemented with 10% fetal bovine serum (FBS, Hyclone, Utah, USA). CNE-1 (a highly-differentiated nasopharyngeal epithelial cell line), CNE-2 (a poorly differentiated nasopharyngeal epithelial cell line) and Sun(e(a poorly differentiated nasopharyngeal epithelial cell line carried Epstein-Barr virus) were maintained in RPMI 1640 with 10% FBS.

**Tissue collection and RT-PCR**

A total of 21 tissues were collected from Sun Yat-sen University Cancer Center. Six paired matched tissues from different organs included esophagus, stomach, liver, lung, cervix and breast; nine nasopharyngeal tissues contained

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**Table 3: Candidate SNPs**

| Number | RefSNP | Contig Position | Variant Alleles | Amino acid change | MAF | HWpval | Genotyped (%) |
|--------|--------|-----------------|-----------------|-------------------|-----|--------|--------------|
| SNP1   | RS17439810 | 39867905 | C, G | Gln104Glu | 0.058 | 0.195 | 74.0 |
| SNP2   | RS1785937 | 39868005 | A, G | Met171Val | 0.271 | 0.999 | 81.4 |
| SNP3   | RS17511578 | 39868252 | A, C | Asn189His | 0.063 | 0.978 | 74.8 |
| SNP4   | RS17588402 | 39926432 | G, A | 5'UTR | 0.118 | 1.000 | 76.2 |
| SNP5   | RS1794001-SNP1 | 39944127 | T, G | Glu181Lys | 0.067 | 1.000 | 89.9 |
| SNP6   | RS2252352 | 39950655 | T, T | intron | 0.054 | 0.562 | 97.4 |
| SNP7   | RS2271395 | 39961241 | G, A | Ala158Thr | 0.368 | 1.000 | 94.8 |
| SNP8   | RS1442855 | 43164843 | G, A | intron | 0.164 | 0.946 | 82.5 |
| SNP9   | RS2347044 | 43273849 | A, G | intron | 0.225 | 0.377 | 96.9 |

RefSNP(RS), SNP accession ID; HWpval, P value of Hardy-Weinberg equilibrium tests for control subjects; MAF, minor allele frequency; % Genotyped, Percent of samples successfully genotyped. New SNPs are shown in bold.

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**Table 4: SNP allele frequency comparison between cases and controls**

| Number | Name | Major Alleles | Case, Control Ratios* | Chi square | P value |
|--------|------|---------------|-----------------------|------------|---------|
| SNP1   | loc123-e3l-snp1 | C, C | 772:42 452:34 | 1.864 | 0.1722 |
| SNP2   | loc123-e3l-snp2 | A, A | 570:227 472:164 | 1.051 | 0.3053 |
| SNP3   | loc123-e3l-snp3 | G, G | 659:51 572:32 | 1.960 | 0.1615 |
| SNP4   | LOC344967 | G, G | 634:74 546:84 | 2.658 | 0.1031 |
| SNP6   | RS17511668-SNP2 | G, G | 802:66 670:40 | 2.419 | 0.1199 |
| SNP7   | RS794001-SNP1 | T, T | 890:48 728:44 | 0.282 | 0.5954 |
| SNP9   | RS2252352 | T, T | 574:320 493:301 | 0.809 | 0.3684 |
| SNP10  | RS2271395 | A, A | 599:331 452:282 | 1.410 | 0.2350 |
| SNP11  | RS1442855 | G, G | 646:128 565:109 | 0.035 | 0.8513 |
| SNP12  | RS2347044 | A, A | 712:212 607:171 | 0.225 | 0.6351 |

*Case, Control Ratios = the frequency of Major Alleles: the frequency of Minor Alleles
2 chronic nasopharynx inflammation (Inf.), 1 Differentiated Carcinoma (DNK), 4 Undifferentiated Carcinoma (NDNK), 1 low differentiated squamous carcinoma (LDS) and 1 non-Hodgkin’s lymphoma (NHL). RNA was extracted using TRIZOL Reagent (Invitrogen, Carlsbad, CA), and reverse transcription was performed using the TaKaRa RNA PCR kit (AMV) Ver.3.0 (TaKaRa BIO, Shiga, Japan). PCR to detect N4BP2 was performed using the following primers (N4BP2-L: 5’-AAAGGGAGACCCTTATGTTTGA-3’; N4BP2-R: 5’-AAATCAAACCTCACTTGCATTT-3’) and Bcl-3 with primers (Bcl-3-L: 5’-tcctctggtgaacctgccta-3’; Bcl-3-R: 5’-gaagaccattggagctgagg-3’) as control with primers (5’-acactgtgcccatctacgagggg-3’ and 5’-atgatggagttgaaggtagtttcgtggat-3’).

### Results

**SNP analysis**

We identified a total of twelve SNP associated with the N4BP2 locus, four of which were upstream of the N4BP2 gene and eight which were within N4BP2 gene (Table 3). Of the SNPs, five SNPs resulted in missense mutations. Three novel SNPs were identified: loc123-e3l-snp2 (position 39868005, allele A/G, resulting in amino acid change Met171 to Val), RS17511668-SNP2 (position 39926432, allele C/T, resulting in amino acid change Arg172 to Gln), and loc123-e3l-snp3 (position 39877628, allele A/G, resulting in amino acid change Pro175 to Ser).

### Table 5: Haplotype analysis

| Block | Haplotype | Frequencies<sup>a</sup> | Case, Control Ratios<sup>b</sup> | Chi Square | P Value |
|-------|-----------|-------------------------|-------------------------------|------------|---------|
| 1(SNP1-4) | CAG | 0.55 | 519.0:411.0, 420.2:357.8 | 0.557 | 0.4556 |
| | CGG | 0.272 | 261.2:668.8, 204.2:573.8 | 0.724 | 0.3947 |
| | CAA | 0.119 | 100.6:829.4, 103.0:675.0 | 2.368 | 0.1238 |
| | GAG | 0.058 | 49.2:880.8, 50.6:772.7 | 1.149 | 0.2837 |
| 2(SNP6-7-9-10) | GTTA | 0.542 | 521.4:426.6, 429.0:377.0 | 0.549 | 0.4589 |
| | GTG | 0.355 | 328.2:619.8, 294.3:511.7 | 0.684 | 0.4082 |
| | AGTA | 0.047 | 40.4:907.6, 41.6:764.4 | 0.806 | 0.3692 |
| | ATTA | 0.017 | 27.4:920.6, 27.7:820.3 | 16.903 | 3.93E-05 |
| | GTTG | 0.016 | 4.6:943.4, 4.9:782.7 | 16.038 | 6.21E-05 |
| | GTCA | 0.015 | 13.1:934.2, 12.9:793.1 | 0.14 | 0.7079 |

B Bold type indicates significant difference between case and control.

<sup>a</sup>Frequency of haplotype in total subjects.

<sup>b</sup>Frequency of haplotype: frequency of non-haplotype.

### Table 6: Permutation test

| Name | Chi Square | Permutation p-value |
|------|------------|---------------------|
| Block 2: ATTA | 16.903 | 0.0007 |
| Block 2: GTTG | 16.038 | 0.0013 |
| Block 1: CAA | 2.368 | 0.8602 |
| Block 1: GAG | 1.149 | 0.9916 |
| Block 2: AGTA | 0.806 | 0.9992 |
| Block 1: CGG | 0.724 | 0.9997 |
| Block 2: GTG | 0.684 | 0.9998 |
| Block 1: CAG | 0.557 | i |
| Block 2: GTTA | 0.549 | i |
| Block 2: GTCA | 0.14 | i |

Haplotype in bold is closely linked block.
Expression of N4BP2 and Bcl-3 mRNA in cells and tissues. (A) Expression of N4BP2 and Bcl-3 mRNA in nasopharyngeal epithelial cell lines. RT-PCR was performed with gene-specific primers and β-actin was used as a control. (B) Expression of N4BP2 and Bcl-3 mRNA in matched tissues. RT-PCR was performed with gene-specific primers and β-actin as a control. up-low: normal tissue; down-low: tumor tissue. (C) Expression of N4BP2 and Bcl-3 mRNA nasopharyngeal tissues. Inf.: chronic nasopharynx inflammation; NDNK: Undifferentiated Carcinoma; DNK: Differentiated Carcinoma; LDS: Low differentiated squamous carcinoma; NHL: non-Hodgkin’s lymphoma.
allele G/A, amino acid change Glu118 to Lys), and RS794001-SNP1 (position 39944127, allele T/G, intronic). However, allele frequency analysis revealed no significant difference between case and control groups (Table 4).

**Haplotype analysis**

Haplotype frequencies and distributions were estimated using a standard EM algorithm. Interestingly, Four SNPs (SNP6-7-9-10) combined haplotype Block 2 ATTA and GTTG exhibited notable difference between case and control groups (Table 5). Permutation tests for allelic association confirmed that block ATTA and GTTG are closely linked (Table 6) and confirmed the difference of Block 2 ATTA and GTTG in cases and controls.

**N4BP2 and Bcl-3 expressed in cells and tissues**

Bcl-3 and N4BP2 were detected in all cell lines examined (Figure 1A). Interestingly, gene expression levels appeared to vary among the cell lines, with the lowest levels being detected in the Sune line. N4BP2 and Bcl-3 mRNA levels appeared to be higher in tumor than in matched normal tissue (Figure 1B). N4BP2 and Bcl-3 were also detected in nasopharyngeal tissues (Figure 1C). These observations suggest that N4BP2 expression levels correlate with the progression of cancer including NPC.

**Discussion**

We previously showed, by linkage analysis that an NPC susceptibility locus maps to chromosome 4 near the LOC344967. Here, we extend this analysis in an effort to identify a bona fide NPC susceptibility gene. N4BP2 is a candidate gene in this region, and we thus sought to examine the correlation between genetic polymorphisms in N4BP2, a mismatch repair gene, and the incidence of NPC. SNPs have been shown to be extremely useful for studying the association between genomic regions and disease [14]. Several studies have demonstrated that polymorphic variation in mismatch repair genes contributes to susceptibility to certain cancers [15,16]. In addition, several pieces of evidence suggest that nasopharyngeal carcinogenesis is associated with individual susceptibility caused by SNPs. Our results show that, although there is no significant difference in SNPs between cases and controls, there are two haplotypes, ATTA and GTTG, the distribution of which differed between case and control groups. Just as the report that almost not any difference in the allele frequencies of five SNPs within the TNFSF4 gene individuals suffered from coronary artery disease versus the controls while there were significantly more frequent of the possible haplotypes from this five TNFSF4 SNPs in individuals with coronary artery disease than controls [17]. Insight into this paradox has been provided in a recent review by Schaid [18]. Haplotypes, the grouping of closely linked alleles on a chromosome, make an important contribution to the study of the genetic basis of disease. Schaid [18] explained that for case-control studies, methodological approach based on haplotype has more advantage than single-locus analysis as the SNPs are in LD with a causative diallelic locus; in particular, haplotype-based methods have greater power when the marker alleles are in strong LD with causative alleles. Haplotype methods are more useful for variants which are more recently evolved, rarer and more causative than for variants which are older and more common. This may help explain why the haplotypes ATTA and GTTG exhibit differences in frequency between case and control groups while individual SNPs do not.

N4BP2 is a Bcl-3 binding protein, and Bcl-3 is an oncoprotein that is overexpressed in certain cancers, including NPC. Our analysis of N4BP2 and Bcl-3 expression levels suggest that expression of these genes is correlated, suggesting they may be co-regulated. We also found that N4BP2 and Bcl-3 are expressed in all NPC cell lines examined and were higher for certain cancers. These observations are consistent with previous reports.

**Conclusion**

Above all, we found that two N4BP2 haplotypes, ATTA and GTTG, are correlated with NPC. This will be useful for predict the development of NPC. In addition, N4BP2 and Bcl-3 mRNA levels were elevated in tumors, including NPC tumors, which suggest new therapeutic targets for fighting NPC.

**Competing interests**

The author(s) declare that they have no competing interests.

**Authors’ contributions**

YXZ and HDQ were responsible for the design of study. MZZ carried out the experiments and drafted the manuscript. HDQ participated in data analysis. XJY and RHZ performed sequencing. LZC and QSF helped in cell culture and tissue collection.

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