

# A Social Network Analysis of Communication about Hereditary Nonpolyposis Colorectal Cancer Genetic Testing and Family Functioning<sup>1</sup>

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## Abstract

**Hereditary cancers are relational diseases. A primary focus of research in the past has been the biological relations that exist within the families and how genes are passed along family lines. However, hereditary cancers are relational in a psychosocial sense, as well. They can impact communication relationships within a family, as well as support relationships among family members. Furthermore, the familial culture can affect an individual's participation in genetic counseling and testing endeavors. Our aims are (a) to describe the composition of familial networks, (b) to characterize the patterns of family functioning within families, (c) to analyze how these patterns relate to communications about genetic counseling and testing among family members, and (d) to identify influential family members. Specifically, we asked how the relationship between mutation status, kinship ties, and family functioning constructs, e.g., communication, cohesion, affective involvement, leadership, and conflict, was associated with discussions about genetic counseling and testing. We used social network analysis and random graph techniques to examine 783 dyadic relationships in 36 members of 5 hereditary nonpolyposis colorectal cancer (HNPCC) families interviewed from 1999–2000. Results suggest that in these five HNPCC families, two family members are more likely to discuss genetic counseling and testing if either one carries the mutation, if either one is a spouse or a first-degree relative of the other, or if the relationship is defined by positive cohesion, leadership, or lack of conflict. Furthermore, the family functioning patterns suggest that mothers tend to be the most**

**influential persons in the family network. Results of this study suggest encouraging family members who act in the mother role to take a “team approach” with the family proband when discussing HNPCC risks and management with family members.**

## Introduction

Hereditary cancers are relational diseases from both a biological and a psychosocial perspective. A primary focus of past research on hereditary cancers has been the biological relations that exist within the families and how genes are passed along family lines. HNPCC<sup>3</sup> is a well-characterized autosomal dominant condition that is associated with germ-line mutations in mismatch repair genes (1). Clinical genetic testing for HNPCC can identify mutation carriers who have a 70–80% lifetime risk for developing colon cancer as well as an increased risk for other types of cancers (2–4). Carriers of a HNPCC-predisposing gene mutation are advised to undergo increased screening and surveillance, including colonoscopy that is performed at an earlier age and at a greater frequency compared with general population guidelines (1, 5). Families at risk for HNPCC can benefit from genetic counseling to learn about their inherited cancer risk and make informed decisions about genetic testing, screening, and prevention options (6–8).

Hereditary cancers are relational from a psychosocial perspective (9). Communication and support relationships within the family can affect an individual's participation in genetic counseling and testing (10). The genetic counseling and testing process may affect the individual who is undergoing these processes as well as his or her entire family (11, 12). Often, consultands desire to learn information for themselves as well as for family members (12, 13). Responsibility for disclosing genetic information lies with the individual family members (14, 15). Family communication about inherited conditions is vital to assure that individuals accurately convey and understand family history information and disclose risk information in a timely manner (12, 16). Barriers to the disclosure of health information and subsequent adherence to prevention and early detection recommendations may be created by difficult family relationships, potential rejection, and protective factors, such as an unwillingness to cause concern or alarm (16–20).

The family culture represents a complex, relational social system that allows the exchange of resources such as information and support. Furthermore, family systems influence action among family members and can change or evolve as a function of these actions (21). It is difficult to understand the complexity

Received 4/24/02; revised 12/30/02; accepted 1/23/03.

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<sup>1</sup> Supported by 2R01HG1200-6, National Human Genome Research Institute, NIH and by the Kleberg Human Cancer Genetics Development Fund. Portions of this research were presented at the annual meeting of the American Association for the Advancement of Science held in Denver, Colorado in 2003.

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<sup>3</sup> The abbreviations used are: HNPCC, hereditary nonpolyposis colorectal cancer; SNA, social network analysis; FDR, first-degree relative; MAR, mean absolute residual; ODR, biological relation other than first-degree relative; OR, odds ratio.

of the family system using methods that focus on the individual and are independent of the system. Instead, methodology that focuses on the individual as an interdependent and integral part of the familial culture can enhance understanding of how multiple components of the family system can influence the actions of both the individual and others within his or her family system.

Previous studies investigating the psychosocial impacts of genetic counseling and testing focused primarily on the proband and relationships specific to the proband and have not fully considered the familial environment and interactions among others in the family system (16, 22). The present study was not limited to family relationships involving the proband but also examined the relationships among other family members as well. This broader consideration enabled us to gain some understanding of how health-related information is diffused through the family system, the characteristics of those family members with whom an individual is most likely to have discussions about genetic counseling and testing, and the characteristics of those family members who are potentially “influential” in encouraging participation in genetic counseling and testing efforts.

There are four aims to the present study. First, we described the composition of familial networks, and, second, we characterized the patterns of family functioning and genetic counseling and testing discussions within the families. Third, we examined how these patterns, or the familial culture, were related to discussing genetic counseling and testing among family members. In the present context, family culture is defined as the kinship ties in the family as well as family functioning relationships, *e.g.*, communication, support, leadership, and conflict. Fourth, we identified the characteristics of individuals with the most influence in the family. Influential individuals may assume responsibility in educating family members about their genetic risk, reminding family members to comply with high risk screening recommendations and convincing family members to participate in genetic counseling and testing.

Social network methods were used to investigate the communication and family functioning patterns among members of five extended families identified as having a HNPCC-predisposing mutation. SNA provides a framework for studying the complexities of a social system such as family and also provides powerful tools that can be used in research involving families and in tailoring interventions that target families (23–26). By investigating the interpersonal relationships among a set of individuals, or actors, social network methodology can provide a detailed map of the social environment within which family members interact and can facilitate an understanding of which aspects of the familial culture influence the discussion and participation in genetic counseling and testing efforts. In this study, we examined the family functioning relationships among a network of family members and friends and how these relationships impact discussions about genetic counseling and testing. In the case of familial cancers and other inherited conditions, the family structure and culture may be particularly important to the diffusion and dissemination of health information, provision of support through family crises, and persuasion of family members to receive genetic counseling to manage their risk including screening and the option of genetic testing.

## Materials and Methods

**Study Population.** Data were collected as part of a qualitative study of family communication and family functioning with

regard to HNPCC genetic testing. Semistructured telephone interviews were conducted with 36 adult members (58% who were female) of 5 extended families who had previously been found to carry HNPCC-predisposing mutations. Family members included those who had been diagnosed with a HNPCC syndrome cancer, unaffected individuals who are at risk of carrying a mutation, and their spouses (25% of all respondents were spouses). The recruitment and interview protocol has been described in detail elsewhere (10). Briefly, colorectal cancer patients at The University of Texas M. D. Anderson Cancer Center were invited to participate in a research protocol that offered free genetic counseling and testing for HNPCC. When patients were identified as mutation carriers, their at-risk relatives (*e.g.*, siblings, children, and other relatives presumed to be at 50% risk of inheriting the mutation) were subsequently invited to participate in the protocols. Individuals who were invited to participate in the genetic testing protocol were also invited to participate in a concurrent longitudinal study of psychosocial aspects of HNPCC genetic counseling and testing. HNPCC mutation-positive families were identified for the qualitative study if (a) the proband had participated in the longitudinal psychosocial study (27, 28) and (b) the family included at least five living members estimated to be at 50% risk of carrying a mutation who were at least 18 years of age and who could speak and read English. Of 35 families who had been identified as HNPCC mutation carriers through the genetic testing protocols, 5 families with a total of 74 relatives eligible for genetic counseling and testing met these criteria. Invitations to participate in the qualitative study were mailed to 63 (85%) biological relatives and 31 spouses whom we were given permission to contact. Of those invited, 45 biological relatives (71%) and 11 spouses (35%) had participated in the longitudinal study. Subsequently, 27 relatives (43%) and 9 spouses (29%) agreed to take part in telephone interviews that were recorded and transcribed; 26 relatives (96%) and 4 spouses (44%), respectively, had participated in the longitudinal study. Of those interviewed, ages ranged between 21 and 82 years, with a mean age of 49 years (SD = 16.5 years). The sample included individuals who had undergone genetic counseling and testing, as well as those who had not. The five families will be referred to as Family A, Family B, Family C1, Family C2, and Family D. Family C1 and C2 represent two separate but related families. Family C1 lives in the United States, and Family C2 lives in Europe.

**Measures.** The study questionnaire was designed to define network membership and to define and measure the social relations within each respondent’s family network. For most genetics studies, family membership criteria generally includes only biological relatives potentially at risk for inheriting a disease-predisposing gene mutation. However, individuals’ perceptions of their family may also include spouses or life partners, adopted children, stepchildren, and, in some cases, very close friends (29, 30), all of whom may be influential or important in communication and family functioning processes. For the present study, the boundaries of who was considered as part of the family network were set by the individual who was interviewed. The interviews opened with the phrase, “Tell me about your family and about close friends who are like family.” These individuals, or *alters*, could be biological family members, family through marital relations (*e.g.*, spouses, life partners, or relatives “in law”), adoption, or friends and coworkers who were considered family.

To investigate the relationship between the familial culture and communication about genetic counseling and testing, we

examined general family functioning using a network perspective. Family functioning was evaluated by the constructs of communication, cohesiveness, affective involvement, leadership, and conflict. The constructs and the items used to measure each of these constructs were derived from theoretical models of family functioning and family functioning questionnaires that were validated and frequently used in studies (31–36).<sup>4</sup> Each of these constructs has both a negative and positive aspect.<sup>5</sup> For example, two of the items used to measure cohesion ask, “Who do you feel close to?” and “Who do you not feel close to?” These items were derived from the Family Adaptability and Cohesion Evaluation Scale III (34) questions “Family members feel closer to other family members than to people outside the family” and “Family members feel very close to each other,” the Index of Family Relations (33) question “There is no sense of closeness in my family,” and the Self-Report Family Inventory (31) question “Our family is proud of being close.” Each of the family functioning constructs will be defined briefly and example questions described below.

The communication construct focuses on those family members with whom the respondent regularly talks (or does not talk) and shares (or does not share) good news and/or bad news. Example questions include “Who do you regularly talk to in your family? How often? What do you talk about?” and “Who do you not talk to in your family?”

Cohesion and affective involvement refer to two types of supportive relationships. Cohesive relationships are supportive relationships that involve family members toward whom the respondent feels close. These close relationships are characterized by support-seeking during a crisis and/or minor everyday upset, or the sharing of confidences. The negative aspect of this construct is defined by a lack of cohesion—those to whom the respondent would not confide in or go to when he or she is upset. Example questions include “During a minor everyday upset, who do you turn to? Not turn to?” and “Who do you feel close to? Who do you not feel close to?” Affective involvement is another type of support relationship that refers to receiving comfort, sharing feelings, and feeling comfortable or safe in expressing oneself. The negative aspect of affective involvement refers to relationships where the alter would not offer comfort, or where the respondent feels uncomfortable expressing his/her feelings. Example questions include “Who comforts you? Is there anyone you would not expect comfort from?” and “When you want to talk about your feelings, who are you comfortable talking with? Uncomfortable?”

Leadership captures advice-seeking and advice-taking relationships. Negative leadership represents coercive relation-

ships, where the respondent might not feel comfortable deviating from the advice given by the alter. Example questions include “Who do you listen to?” “Whose advice do you take?,” and “Is there someone whose suggestions you feel you must follow? In other words, someone you would never cross?” Conflict refers to the open expression of anger, aggression, and conflict among family members. Relationships characterized by a lack of conflict involve family members with whom the respondent gets along well. Example questions include “With whom do you get along well?” and “Is there anyone in your family that you do not get along with?”

In addition to the family functioning constructs, we also measured communication relationships specific to genetic testing and counseling. Discussing genetic counseling and testing was similarly measured as a relation that captured communications specific to genetic testing. The negative aspect of this communication construct captured relationships characterized by a lack of discussion about genetic testing and counseling. Example questions include “Who have you talked to about the genetic counseling and testing?” and “Whom haven’t you talked to about the genetic counseling and testing?” Negative affective relationships have rarely been studied in the familial communication and family functioning domain (25). In this study, we examined how negative familial relationships may or may not be related to genetic counseling and testing communication.

The relational value for each dyad was calculated as the proportion of items the respondent selected the family member in answer to the questions for each of the family functioning constructs and the communications about genetic counseling and testing relations. The SNA techniques used to investigate the familial environment in this study assume that the measured relations are dichotomous. Therefore, the construct scores were dichotomized such that any value other than a value of zero was scored as a 1. For example, if Respondent  $i$  turns to alter  $j$  during an everyday upset, then the relational tie from  $i$  to  $j$  is coded as a 1 on cohesion.

**Statistical Analysis.** SNA describes the social environment or culture within a family through indices of relatedness and representations of social structures and social positions among family members. The network paradigm is grounded in the following propositions: (a) actors and their actions are necessarily interdependent; (b) relationships, or relational ties, between actors serve as conduits for resources, such as advice, support, and information; and (c) the structure of the social network, or social environment, can constrain as well as potentiate individual action (37). We assumed that the relationships within a family were interdependent, that individuals within the family provided resources to each other, and that family members facilitated, as well as hindered, participation in genetic counseling with the option of testing.

The strength of the network approach lies in the fact that the relationships among a group of social actors can be described as well as how these relationships may affect or influence each other, rather than studying the individual as an isolate. Thus, the method allows us to describe the social environment using structural indices of the actors under investigation. In this paper, we focus on the composition of respondents’ familial networks, *multiplex* relations, and *actor prestige*. Network composition refers to the relative proportion of varying role relations or relationships of varying intensity observed in the network. For example, we might be interested in knowing the proportion of FDRs in a respondent’s familial network. Multiplexity is the degree that multiple role relations

<sup>4</sup> To our knowledge, there are no existing scales that measure family functional relationships at the level of each individual dyad; rather, existing scales measure family functioning at the aggregate level. Because there were no previously developed measures that met our needs, we modified items from validated scales for our study. The family functioning network items were adapted from psychometrically sound instruments and modified to capture the specific qualities of individual family relationships. These modified items enabled participants to discuss differences in each of their familial relationships. Not all items from any particular instrument could be modified to capture this relational information, so we aggregated across common items in several instruments.

<sup>5</sup> Because of the complexity (e.g., on average, each respondent is providing information about 22 dyadic relationships for each family functioning item) and the inherent dependency in the data, standard psychometric techniques are inappropriate. However, we examined the relationship between each pair of family functioning constructs and found that the measures of positive relations were positively associated with each other, the measures of negative relations were positively associated with each other and that there is no association between the positive and negative relations. This is consistent with what would be expected and represents a form of construct validity.

are exhibited in the network. In the present study, we are interested in whether there is a multiplex relation between supportive relationships and communication about genetic counseling and testing: for example, is there a tendency for participants to discuss genetic counseling and testing with those toward whom they feel close? Prestige will provide an index that identifies influential family members. We examined whether or not there is consensus among participants within a family about who exerts influence. Furthermore, we assessed whether prestigious individuals across families share common characteristics.

**Composition of Family Networks.** To investigate the composition of our respondents' family networks, we computed the number of individuals, or alters, named as family, the percentage of alters who were biologically related to the respondent, the percentage of alters who were related to the respondent through marriage, the percentage of alters who were at risk of carrying the HNPCC mutation, and the percentage of alters who were female. The mean and *SD* for each of these composition variables were computed for each family.

**Patterns of Family Functioning and Communication.** The patterns of family functioning were investigated by computing the proportion of the dyadic relationships in each family, as reported by the set of respondents, that are characterized by the family functioning constructs and discussions (or lack of discussions) about genetic counseling and testing. The nature of the genetic counseling and testing discussions was further characterized with respect to general discussions about genetic counseling and testing, discussions specific to the respondent receiving genetic counseling and testing, and the disclosure of genetic testing results.

**Relationship between Familial Culture and Genetic Counseling and Testing Discussions.** To investigate the relationship between the family functioning constructs and communication about genetic counseling and testing, we used random graph modeling techniques. Wasserman and Pattison (38, 39) developed models for complete networks that allow the investigator to examine the structure of relationships within a network. These models provide a framework for investigating questions concerning the association between multiple relations. Building on the work of Wasserman and Pattison, Koehly *et al.* (40) showed the applicability of these random graph models to egocentric network data. The network data collected in the present study represent a set of ego-centered networks, in which the respondent represents the *ego*, and the respondent's family members are the *alters*. Thus, we are investigating the relationship between the familial culture and discussions about genetic counseling and testing as it is perceived by those family members who agreed to be interviewed.

With the exception of Family C1 and Family C2, all respondents' personal networks are interconnected within families, but independent between families. Although no members of Family C2 were referred to by respondents from Family C1, two of the family members from Family C1 were mentioned by respondents from Family C2. Thus, these individuals acted as conduits of information, or "bridges," between the two families. Random graph models allow us to incorporate the interdependence of relations within families as well as the interdependence between Families C1 and C2.

Markov dependence was assumed within each family, and relationships were assumed to be dependent if they shared a family member in common. The Markov dependence model controls for the number of relationships reported within a family, the reciprocal relationships reported between study par-

ticipants, variability among the number of alters in each participant's family (out-stars), and the variability in the number of participants' families within which particular alters are members (in-stars). Furthermore, each study participant provided their own setting structure (compare Ref. 41) based on their definition of family. The results from these analyses should be interpreted as conditional on the perceptions of the respondent.

Model parameters were estimated via maximum pseudo-likelihood estimation (compare Refs. 42–44). The importance of model parameters was based on the conditional pseudo-likelihood ratio statistics obtained by comparing the pseudo-likelihood ratio statistics ( $G^2$ ) from two nested models, one with the predictor of interest and one without, and a comparison in the mean of the absolute difference between the observed relational ties and those predicted from the model, or *MAR*. The dependent variable in this analysis is the family network as defined by who discussed genetic counseling and testing. Predictor variables in the analysis included the mutation status of the respondent, the mutation status of the alter, the kinship ties between the alter and the respondent (*e.g.*, FDR, spouse, friend), and the networks defined by the family functioning relations (communication, cohesion, affective involvement, leadership, and conflict). The total number of dyadic relationships included in the analysis is 783. Given the large number of relationships and the fact that the distributional properties of the conditional pseudo-likelihood ratio statistics are largely unknown at this time, we used a stringent Type I error rate (*e.g.*,  $p < 0.005$ ).

**Influential Family Members.** Prestige indices, based on normalized indegree, were computed for each alter in the family. Normalized indegree, in the present context, is defined as the proportion of times each alter was "chosen" by the respondents on the social relation of interest. Normalized indegrees were computed for each alter on each social relation (*e.g.*, communication, conflict, genetic counseling and testing discussions). For the family functioning constructs, a composite influence score was computed by aggregating the normalized indegrees for those constructs that have a strong association with discussions about genetic counseling and testing in the family. Those family members with the largest prestige indices on the family functioning composite and in discussions about genetic counseling and testing were characterized in terms of kinship role, mutation status, and gender.

## Results

**Kinship Ties among Study Participants.** The following results should be interpreted within the context of the dyadic kinship ties among the study participants; these kinship relations are described in Table 1. There is large variability in the percentage of first-degree relationships (*e.g.*, parent-child and sibling) among study participants. All respondents from Family B share biological ties with each other, and between 36% and 67% of the relationships among respondents from other families have a biological link.

**Composition of Family Networks.** Table 2 presents an overview of the composition of each study participant's personal familial network. On average, each respondent has approximately 21.7 (*SD* = 6.3) individuals named as family, 20% of whom are not based on biological or marital connections but rather are friends. Even though the respondents were aware that the study focused on HNPCC, they did not limit their responses to those who are at risk for the condition. The respondents' familial networks were fairly balanced in terms of gender distribution, except for Family C2.

Table 1 Kinship relations among study participants from five HNPCC-carrier families, 1999–2000

	Family A (36 dyads)	Family B (21 dyads)	Family C1 (10 dyads)	Family C2 (21 dyads)	Family D (28 dyads)
Generations ( <i>n</i> )	3	2	2	1	3
% Sibling	17	43	10	67	7
% Parent-child	11	14	20	0	4
% (Great) aunt/uncle-niece/nephew	28	43	10	0	21
% Spouse	6	0	20	7	7
% In-law <sup>a</sup>	38	0	40	26	61

<sup>a</sup> Includes son-/daughter-in-law, father-/mother-in-law, brother-/sister-in-law, and aunt/uncle through marriage.

Table 2 Family network composition for study participants in five HNPCC-carrier families, 1999–2000

	Family A	Family B	Family C1	Family C2	Family D
No. of respondents	9	7	5	7	8
Mean no. in each participant's network ( <i>SD</i> )	19.9 (4.4)	18.6 (5.2)	25.0 (11.3)	21.7 (4.5)	24.6 (5.6)
Biological or marital family, mean % ( <i>SD</i> )	79.6 (10.0)	81.2 (12.0)	80.4 (13.0)	79.2 (7.4)	84.0 (9.6)
Biological family, mean % ( <i>SD</i> )	50.4 (23.2)	68.6 (14.2)	49.2 (14.0)	62.1 (22.0)	45.4 (14.9)
Family members at risk for carrying the HNPCC mutation, mean % ( <i>SD</i> )	51.1 (13.4)	60.3 (15.3)	45.7 (14.1)	52.3 (9.8)	48.7 (11.3)
Female, mean % ( <i>SD</i> )	59.0 (8.9)	50.7 (7.4)	57.9 (5.8)	36.3 (6.5)	52.5 (8.5)

**Patterns of Family Functioning and Communication.** Table 3 shows the proportion of dyads in each family reporting positive and negative family functioning relational ties on the measured construct. The families do not differ on any ties related to family functioning constructs except communication and lack of conflict. Compared with the other families, Family D reports the lowest amount of communication among family members (52.3%), and Family A reports the least amount of conflict among family members (52.5%). Data in Table 3 indicate that there are some, albeit few, familial relationships that exhibit negative aspects of family function; however, the relationships among members in all families generally appear to have a higher occurrence of positive than negative aspects of family functioning.

There is a statistically significant difference across the five families in the number of family members with whom respondents reported that they had discussed genetic counseling and testing. Family B reports the highest rate of discussion about genetic counseling and testing, which is not surprising, given that all of the respondents from this family are biologically related and that respondents reported the highest proportion of biological family and the highest proportion of family members at risk for carrying the HNPCC mutation in their networks.

Questions involving communications about genetic counseling and testing focused on discussions about counseling and testing and the disclosure of genetic testing results. Given that there was some discussion about genetic counseling and testing, 81% of these communications were general discussions about counseling and testing, 32% involved the respondent getting counseling and testing, and 47% involved the disclosure of genetic test results either by the respondent or the alter. Genetic counseling and testing was not discussed with everyone whom respondents named in their networks, although there were very few alters (6% across all five families) with whom respondents indicated that they refused to discuss genetic counseling and testing. In most cases, respondents refused to discuss genetic counseling and testing with family members who were under the age of 18 years. No further analyses were conducted on this variable due to the lack of variability.

**Relationship between Familial Culture and Genetic Counseling and Testing Discussions.** All analyses presented assume a Markov dependence among the relationships within each family, and the degree of dependence was allowed to vary across families. Additionally, the mutation status of both the respondent and the alter was included in each fitted model. This base model has a *MAR* of 0.344 and a pseudo-likelihood ratio statistic equal to 808.71. The mutation status of both the respondent and the alter showed large effects in explaining genetic counseling and testing discussions. The parameter estimates are 0.776 (*SE* = 0.235; *p* = 0.001) and 1.192 (*SE* = 0.390; *p* = 0.002) for respondent status and alter status, respectively. This indicates that there is an increased likelihood that two family members discussed genetic counseling and testing if at least one had a positive mutation status. For the set of models discussed below, there were no significant differences between families in the association between the family functioning relationships and genetic testing and counseling communication.

The first set of analyses examined the bivariate relationship between the respondent and alter kinship ties and whether they discussed genetic counseling and testing, controlling for Markov dependence and mutation status. The kinship ties that were investigated include FDRs, ODRs, spousal or life partner relation, marital relation other than spousal (*e.g.*, in-laws), and friend. Both FDR and spousal relationships were statistically important ( $\Delta G^2 = 76.15$ ; *p* < 0.001; *MAR* = 0.305). The parameter estimate for FDR relationships (1.434; *SE* = 0.213) indicates that respondents are more likely to discuss genetic counseling and testing with FDRs than with other family members (*OR* = 4.2). Similarly, the parameter estimate for spouse (3.212; *SE* = 0.606) indicates that respondents are also highly likely to discuss genetic counseling and testing with their spouses or life partners (*OR* = 24.8).

The relationship between the family functioning constructs and whether respondents communicated about genetic counseling and testing was examined, controlling for Markov dependence and mutation status. Table 4 shows the fit statistics along with the parameter estimates and their associated *SEs* for the important family functioning constructs as predictors of

Table 3 Proportion of family network dyads reporting family functioning relational ties for five HNPCC-carrier families, 1999–2000

Family functioning constructs	Family A (179 dyads)	Family B (130 dyads)	Family C1 (125 dyads)	Family C2 (152 dyads)	Family D (197 dyads)
Communication (+) <sup>a</sup>	0.704	0.585	0.688	0.658	0.523
Communication (-)	0.100	0.115	0.096	0.092	0.091
Cohesion (+)	0.508	0.531	0.440	0.579	0.376
Cohesion (-)	0.028	0.123	0.008	0.013	0.056
Affective involvement (+)	0.464	0.385	0.464	0.507	0.523
Affective involvement (-)	0.201	0.185	0.200	0.145	0.173
Leadership (+)	0.385	0.369	0.312	0.362	0.365
Leadership (-)	0.017	0.015	0.008	0.020	0.025
Lack of conflict (+) <sup>a</sup>	0.525	0.369	0.264	0.250	0.279
Lack of conflict (-)	0.106	0.054	0.040	0.085	0.071
Genetic testing discussion (+) <sup>a</sup>	0.425	0.639	0.336	0.566	0.365
Genetic testing discussion (-)	0.000	0.046	0.064	0.092	0.086

<sup>a</sup>  $p \leq 0.001$  (based on a  $\chi^2$ , degrees of freedom = 4).

Table 4 Fit statistics, parameter estimates, and estimated SEs for random graph models investigating association between family functioning constructs and discussing genetic counseling and testing in five HNPCC-carrier families, 1999–2000

Family functioning construct	Bivariate conditional $G^2$ (MAR) <sup>a</sup>	Parameter estimate (SE)	Bivariate conditional $G^2$ (MAR) <sup>b</sup>	Parameter estimate (SE)
Communication				
(+)	55.95 <sup>c</sup> (0.318)	1.488 (0.211)	33.87 <sup>c</sup> (0.290)	1.241 (0.222)
(-)	0.043 (0.343)		1.13 (0.305)	
Cohesion				
(+)	109.51 <sup>c</sup> (0.289)	1.988 (0.203)	73.70 <sup>c</sup> (0.270)	1.746 (0.212)
(-)	2.71 (0.342)		2.20 (0.304)	
Affective involvement				
(+)	94.37 <sup>c</sup> (0.296)	1.866 (0.206)	60.25 <sup>c</sup> (0.276)	1.607 (0.216)
(-)	8.38 <sup>d</sup> (0.339)	0.697 (0.240)	0.31 (0.305)	
Leadership				
(+)	101.92 <sup>c</sup> (0.292)	2.011 (0.213)	62.57 <sup>c</sup> (0.276)	1.688 (0.223)
(-)	3.82 (0.342)		0.14 (0.305)	
Lack of conflict				
(+)	59.25 <sup>c</sup> (0.313)	1.665 (0.224)	39.99 <sup>c</sup> (0.285)	1.448 (0.234)
(-)	4.59 (0.341)		0.47 (0.305)	

<sup>a</sup> Analysis controlled for Markov dependence and mutation status of the respondent and alter.

<sup>b</sup> Analysis controlled for Markov dependence, mutation status of the respondent and alter, FDR relationship, and spousal relationship.

<sup>c</sup>  $p < 0.001$  (based on a  $\chi^2$ , degree of freedom = 1).

<sup>d</sup>  $p < 0.005$  (based on a  $\chi^2$ , degree of freedom = 1).

communication about genetic testing. All five positive constructs were significantly associated with whether respondents discussed genetic counseling and testing, with *ORs* ranging between 4.4 and 7.5. Only one negative construct, lack of affective involvement, was positively associated with communication about genetic counseling and testing. This suggests that individuals are 2 times more likely to talk about genetic counseling and testing with family members with whom they are uncomfortable sharing their feelings or from whom they do not expect comfort compared with those with whom they have no negative affective involvement.

Table 4 also provides the contribution of each of the sets of family functioning constructs after controlling for Markov dependence, mutation status, and FDR and spouse relationships. For the five sets of family functioning scales, none of the negative constructs were significantly related to whether or not respondents discussed genetic testing when the kinship tie (FDR, spouse or life partner) was included in the model. For each of the positive family functioning constructs, there is a significant positive parameter estimate, indicating an increased likelihood that the respondent discusses genetic counseling and testing with those whom he/she has a functional family relationship.

Table 5 presents a final series of multivariate models fit to examine which of these family functioning constructs remains important when all are allowed to contribute to the model. A construct was removed from the model if it was not significant, using conditional pseudo-likelihood ratio statistics, based on a significance level of  $p < 0.005$ . The positive communication and affective involvement relations did not remain important when positive cohesion, positive leadership, and lack of conflict were included in the model. The *MAR* for this final model was 0.251, which represents a reduction of 0.093 when compared with the base model. The pseudo-likelihood ratio statistic for the final model is 619.99, which is a reduction of 188.72 when compared with the base model. The parameter estimates, *SEs*, and conditional *OR* for each predictor in the final model are given.

**Influential Family Members.** Based on the results from the final model, the composite prestige index for family functioning was computed by aggregating the normalized indegrees for cohesion, leadership, and lack of conflict. The maximum value for the composite influence score is 3.00. A composite score of 2.00 suggests that two of three respondents, on average, mentioned this family member as being close, providing advise-

Table 5 Parameter estimates, SEs, and conditional ORs for multivariate model of kinship roles, family functioning constructs, and discussing genetic counseling and testing in five HNPCC-carrier families, 1999–2000

Predictor	Parameter estimate (SE)	Conditional OR
Mutation status (respondent)	0.565 (0.275)	1.760
Mutation status (alter)	1.152 (0.450)	3.165
Spouse	2.285 (0.680) <sup>a</sup>	9.827
FDR	0.857 (0.240) <sup>a</sup>	2.357
Cohesion	1.227 (0.230) <sup>a</sup>	3.410
Leadership	1.100 (0.245) <sup>a</sup>	3.005
Lack of conflict	0.927 (0.256) <sup>a</sup>	2.527

<sup>a</sup>  $p < 0.001$ .

ment, and someone with whom one gets along. The most influential persons for each family were examined. One family member from Family B, Family C1, and Family D was singled out by the respondents as being influential in terms of cohesion, leadership, and lack of conflict with a composite score equal to 2.00 for Family B and Family C1 and 1.75 for Family D. In all three of these families, this individual was female. For Family B, her kinship roles are mother and a sister; for Family C1, her kinship roles are mother, wife, and sister-in-law; and for Family D, her kinship roles are mother, sister, wife, sister-in-law, and niece. Families A and C2 have more than one member who received high normalized prestige scores on cohesion, leadership, and lack of conflict. In Family A, two family members had composite influence scores equal to 1.89, indicating a strong influence on the family, and both of them are mothers (one is also a wife, and the other is a sister and daughter). In Family C2, where both parents are deceased, five siblings (brothers and sisters) had extremely high normalized prestige values on cohesion, leadership, and lack of conflict with composite influence scores larger than 2.10. Of these 10 influential individuals, one was the proband, two were wives of the proband, and the rest were biologically connected to the proband.

Examining the normalized indegree for the dependent variable (discussing genetic counseling and testing), we see a slightly different pattern of “influence.” To compare these results with the family functioning prestige index, we used a value of 0.58 to represent our cutoff of large. This is equivalent to a family functioning composite index of 1.75 ( $1.75/3.00 = 0.58$ ). Of the 5 families, 22 individuals received large normalized indegrees for the dependent variable; 55% of these 22 individuals had a positive mutation status, 18% did not participate in testing or refused results, 18% had a negative mutation status, and 9% were not in the blood line. Eight of the 10 who are influential based on the family functioning constructs were active participants in discussions about genetic counseling and testing. The two who were not active were wives of the proband. In addition, one member of Family C1 was mentioned by 71% of the study participants from Family C2, suggesting that this individual was influential in bridging Family C1 with Family C2.

## Discussion

To our knowledge, this is the first study to use social network methodology to examine the communication and family functioning relationships among members of families with known HNPCC-predisposing mutations. Using this approach permitted us to move beyond the question of “was the family informed?” to describe the network of discussion about HNPCC among five comparably functional families. Our findings indi-

cated that there were systematic patterns in the flow of discussion across the five families and that discussions are associated with the psychosocial characteristics of individual relationships. The discussions were not simply a function of mutation status and kinship relations. Because disclosure of mutation status and discussions concerning genetic counseling and testing tend to occur more frequently in one-on-one discussions rather than in family meetings (10), it is important to understand the characteristics and contexts of multiple family relationships.

Our results showed that discussion of genetic counseling and testing is not necessarily limited to persons only at biological risk for HNPCC. This discussion also occurs with family members who are not biologically related as well as friends, and these persons may be important in the communication and support process regarding genetic counseling and testing. It is important to allow respondents to define who is family to capture all persons who may play a role in this process. The average family size in this study was 22 persons, approximately 26% of whom were family through marriage (spouse or in-law relation), and 20% of whom were friends. Although approximately half of the family members interviewed in this study were not at risk of carrying a HNPCC mutation, all family members may offer important resources such as support and advice and may be influential in encouraging those at risk to adhere to screening and surveillance recommendations (45). Friends may play a particularly important role in the psychological well being of individual family members. Koehly *et al.* (46) found a relationship between breast cancer patients’ friendship networks and their affective mood state and coping strategy during diagnosis and treatment. Future studies should investigate the specific roles that these individuals, particularly friends, play in the lives of those at risk for HNPCC, especially their influence in adopting or maintaining positive health behaviors.

Our findings regarding the association between the family functioning constructs and communications about genetic counseling and testing tell an interesting story. The bivariate and expanded bivariate analyses found an increased likelihood that family members discussed genetic counseling and testing with their FDRs and their spouses; in other words, within nuclear families. Thus, information is passed from sibling to sibling and from parents to children, which is consistent with previous studies (12, 47). However, this discussion was less likely to occur among ODRs, suggesting a systematic pattern of diffusion of information about genetic counseling and testing through the family network. Our data suggest that an interruption in transmission of risk information to successive generations may occur due to the death of a sibling or parent. Among our respondents, there does not appear to be a tendency for aunts and uncles to discuss risk information with their nieces and nephews, potentially leaving these individuals without information or support regarding cancer risk management, particularly if their parent died from a HNPCC-associated cancer.

Our results also suggest that kinship relation alone may not be sufficient to explain families’ patterns of communication about genetic counseling and testing. Characteristics of the dyadic relationships defined by general communication patterns, support patterns, leadership relations, and lack of conflict were also important in understanding which family members discuss genetic counseling and testing. These results suggest that persons who wish to encourage their FDRs to have genetic testing may need to develop a team approach. Family functioning relationships may help in choosing the best person to encourage other

family members to address the problems associated with being at risk of inheriting a HNPCC-predisposing mutation.

Surprisingly, we found a positive association between discussing genetic counseling and testing and negative affective involvement in bivariate analysis. However, when we controlled for FDR and spousal or life partner relation, negative affective involvement was no longer an important predictor of genetic counseling and testing communication. These findings suggest that although relationships between FDRs may be colored by negative affect, essential communication about the availability of genetic counseling and testing may not necessarily be precluded as a result. Persons may be willing to share important health information, such as the news about the presence of a HNPCC-predisposing mutation in the family, with relatives whom they may not feel comfortable discussing other matters in general.

Communication about genetic counseling and testing was more likely to occur if family members were FDRs, spouses, and/or have a close relationship (cohesion), if they generally listened to each other and took each other's advice (leadership), and if they generally get along with each other (lack of conflict). It is interesting to note that the mutation status of the respondent and the alter was not a significant predictor of discussions about genetic testing and counseling when kinship role and family functioning relationships were included in the model, suggesting that family culture may play a more important role in determining when these discussions occur compared with mutation status.

Communication and affective involvement were not important predictors of discussions of genetic counseling and testing when cohesion, leadership, and lack of conflict were included in the model. The cohesion and leadership constructs may have captured those aspects of communication that were important with regard to discussions about genetic counseling and testing. The cohesion construct captured supportive relationships defined by sharing confidences, feeling close, and turning to during a minor upset, and the leadership construct involved advice-seeking and decision-making relationships. This suggests that patterns of communication associated with discussions about genetic counseling and testing may tend to be characterized by support-seeking and advice-seeking relationships. The affective involvement construct captured relationships in which individuals feel comfortable sharing their feelings and crying openly. Peterson *et al.* (10) reported that HNPCC genetic counseling and testing were not viewed as a crisis; thus, the aspects of affective involvement associated with discussing genetic counseling and testing, such as comfort-seeking, may have been captured by the cohesion and lack of conflict constructs.

The role that women, particularly mothers, play in the family warrants further investigation. The pattern of influence indicates that women, especially mothers, may play an important role in the familial culture, particularly in the context of communications about genetic counseling and testing. This is consistent with other studies that have described women's roles in communicating genetic information (16). Although mothers appear to be potentially influential in the present study, their influence may not necessarily extend to HNPCC genetic counseling and testing, particularly if they are not personally at risk. Other studies that have described mothers' roles in disseminating genetic information have focused on genetic testing for hereditary breast and ovarian cancer (16, 18), a condition that confers the greatest inherited cancer risk to women. Mothers may be more aware about the importance of communicating information about inherited breast cancer risk to their daughters

compared with other inherited syndromes that affect both genders more equally, such as HNPCC. Genetic counselors may need to tailor their counseling to make mothers more aware of their potential influence in communicating about risk for HNPCC. Further research is needed to determine whether similar patterns in women's, especially mother's, roles in communicating genetic information persist across other ethnically and culturally diverse groups.

Future research also should attempt to evaluate the relationship between individuals' responses on psychological measures and their family culture. For example, subgroups of individuals may be at increased risk for experiencing psychological distress during the genetic counseling and testing process (28). It may be important to examine how individuals' psychological responses and adaptation to the counseling and testing process influence the way genetic information is diffused through the family network and how family functioning is impacted as a result.

This study has several limitations. Given the small number of families represented, it is difficult to generalize the results to all other families at risk for HNPCC. It also is important to note that this study was conducted in the context of a larger research protocol that attempted to recruit probands and their at-risk relatives for free genetic counseling and testing. Many individuals who were interviewed had previously agreed to participate in the genetic counseling and testing study, and as a result may be highly self-selected. Also, because at-risk relatives of mutation-positive probands were actively recruited to participate in genetic counseling and testing as part of the larger study, the recruitment effort may have influenced their decision to participate in testing and may have prompted greater communication about genetic testing within these families. However, the cascade method of offering genetic counseling and testing did not seem to restrict discussions of genetic counseling and testing. Family members discussed the issue with close family and friends, but not with more distant relatives, nor did they show a desire to discuss the issue with more distant relatives. The low response rate, 43% of relatives and 29% of spouses, does create a view of communication among individuals who are more likely to participate in studies; however, their view of family discussions about genetic counseling and testing were similar across families. The spousal interviews corroborated the genetic counseling and testing discussion descriptions provided by biological relatives. The cascade method of offering genetic counseling and testing did not affect the diffusion of genetic information in these families because family members did discuss HNPCC with their FDRs. Because not all potential participants in these families agreed to be interviewed, the family culture described in this paper may represent only the perceptions of those who agreed to be interviewed.

However, the representations of the family cultures provided by those who did participate from the five families are very similar. The size of participants' familial networks, the proportion that is family (both biological and through marital ties), and the proportion of relationships characterized by each of the family functioning constructs are relatively consistent across families. Furthermore, there were no family differences in the size of the associations between the family functioning constructs and discussions concerning genetic counseling and testing.

The interviews were conducted retrospectively, and focused on individuals' prior experiences with communicating about HNPCC genetic counseling and testing in their families. This retrospective approach makes it difficult to accurately track the diffusion of mutation status information through the



family network and its impact on family function. Future research should incorporate a prospective framework to understand how the family culture influences diffusion and communication of genetic information and how the family culture changes or evolves as a function of this information.

Despite limitations, this study demonstrates the usefulness of social network methodology in evaluating the family functioning patterns within a family within the context of genetic counseling and testing. The family culture can impact how relatives discuss and share information about genetic counseling and testing. Our findings may have implications for both research and clinical practice in cancer genetics because the family culture may play a significant role in determining who participates in genetic counseling and testing and potentially in determining who adheres to recommended screening and surveillance guidelines. Genetic counselors and others who provide care for persons at risk for hereditary cancers should consider the roles of all persons in an individual's entire social network that may influence how individuals make and cope with genetic counseling and testing decisions, in particular, the roles that nonbiological relatives and friends in the social network play in diffusing information about cancer genetic counseling and testing. Genetic counselors and other providers can assess and use relational information (e.g., cohesion, leadership and lack of conflict) to identify family members who may be particularly influential and supportive with regard to counseling and testing decisions, as well as persons who may be barriers to the diffusion of information. By using such relational information, genetic counselors and other providers can attempt to facilitate the involvement of influential persons in optimizing a family's management of their hereditary cancer risk.

### Acknowledgments

We thank Sapna Kapoor and Linda Solomon for assistance with data collection, Mary Fitzgerald and Heather Kitzman for assistance in developing the interview guide, and Dr. Mindy Bergman, Dr. Timothy Cavell, Dr. Phillipa Patison, Dr. Garry Robins, and Patricia Ward for advice and consultation. In the revision of this article, we profited from comments made by two anonymous referees.

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## A Social Network Analysis of Communication about Hereditary Nonpolyposis Colorectal Cancer Genetic Testing and Family Functioning

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*Cancer Epidemiol Biomarkers Prev* 2003;12:304-313.

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