Spatial Modeling of Colonic Lesions With Geographic Information Systems

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Background: Geographic information system (GIS) software has been used in health care systems to display and analyze spatial pattern of diseases and health services.

Objectives: This study was performed to assess spatial patterns of colon's pathologic lesions based on the pathologic reports and assess whether it is possible to use GIS software in health services.

Patients and Methods: Archives of pathology of Namazi and Faghihi hospitals, two main referral centers of south-west of Iran, were obtained and reviewed between January 2009 and September 2011 for biopsy reports of patients who underwent colonoscopy. Abnormal biopsies were categorized into five different subgroups according to the type of pathologic specimens. By GIS, spatial patterns of colon biopsies were plotted in different maps and spatial auto-correlation of colon biopsies was calculated using the Moran's Index.

Results: A total of 4815 biopsies from 2663 different patients were reviewed, 53.8% of which were men. Abnormal biopsies were 2781 of all specimens (57.8%). Neoplastic lesions, inflammatory bowel diseases and polyps were 9.3%, 19.3% and 29.2% of total biopsies, respectively. Pathologic biopsies were more common in the distal colon. Maps of all biopsies and maps of specific pathologies were manifested in GIS.

Conclusions: Our study showed that left-sided lesions are still more common in the Iranian population. On the other hand, surveying the right side of colon is as important as the distal part, which necessitates total colonoscopy.

Keywords: Geographic Information systems; Colonoscopy; Colorectal Neoplasms; Inflammatory Bowel Diseases; Colonic Polyps

1. Background

During the recent decades, many studies have focused on anatomic location of colorectal diseases and their distribution. According to previous studies, distribution pattern of colorectal cancer (CRC) has been changed since 1980s and the proportion of proximal colon cancer has been increased, while the percentage of distal CRC decreased (1-5). The location of colorectal polyps also plays an important role, for example dysplasia is more common in proximal ones (6, 7). The location of subtypes of inflammatory bowel diseases (IBD) alters the course of disease and influences the probability of neoplasia (8-12). Geographic information system (GIS) is a powerful computer software, which enables investigators to prepare a reliable database exhibiting a geographical pattern of various diseases and health care services (13). Many studies have been conducted on public health management, cancer assessment and distribution of diseases using GIS in Iran (14-17). In addition to these abilities, GIS may also act as a key utility to determine the location of lesions in the human body. One of the best examples of GIS usage is the Biomedical Informatics Research Network (BIRN) project. Many investigators worked on the BIRN project to design a GIS-based infrastructure, for example in providing data on brain morphology and function to illuminate the particular mechanisms and proper treatments for schizophrenia, Alzheimer's, Parkinson's and different types of dementias (18). The application of GIS was also introduced to evaluate the outcomes of transanal endoscopic microsurgery aimed to localize and remove rectal lesions (19, 20).

2. Objectives

The purpose of this study was to determine the location of various pathologic lesions of colon using GIS according to patient's age and gender. Our goal was to provide useful data to improve the quality of colonoscopy according to the pattern of locations of lesions caused by various colorectal diseases.

3. Patients and Methods

3.1. Study Design and Settings

In this cross-sectional retrospective study, archives of pathology in Namazi and Faghihi hospitals, affiliated to

Shiraz University of Medical Sciences, Shiraz, Iran, were reviewed for reports on all patients who underwent colonoscopy between January 2009 and September 2011. Data sheet included 5126 biopsies sorted by patient's name, gender, age at the time of diagnosis, location of pathology and type of pathology. One or more different biopsies obtained from a single patient were included in this study. Reports of lesions without a specific colonic location were considered as undetermined and excluded from the study. The total number of missing data was less than 1%, which could not change our findings principally. This study was reviewed and approved by the local ethical committee of Shiraz University of Medical Sciences. There were five basic groups of colon specimens and biopsies according to the pathological reports. The first one was neoplastic lesions including primary CRC and metastatic malignancies. The second group consisted of Crohn's disease (CD) and ulcerative colitis (UC) as IBD. Unclassified IBD was categorized in this group as indeterminate colitis. Benign and neoplastic polyps encompassed the third group. Other rare and specific pathologic changes were categorized as others in the fourth group. The fifth group was attributed to nonspecific pathological changes, which cannot be classified in previously mentioned groups (Table 1).

3.2. Mapping Methods

Schematic image of large intestine was drawn and inserted in the ArcGIS software version 10.1 (ESRI, Redlands, CA, USA). Then it was divided into nine anatomic regions as follows: Cecum (CC) excluding appendix, ascending colon (AA), hepatic flexure (HF), transverse colon (TR), splenic flexure (SF), descending colon (DD), sigmoid (SS), rectosigmoid junction (RS), and rectum (RR) excluding the anal canal. Due to lack of information about the exact position of each individual biopsy, each group of biopsies was distributed uniformly by using "random points systems" in the ArcGIS software. At first, all pathologic reports were used for demonstration of thematic cartography of the colon biopsies. Then by exclusion of normal biopsies and the fourth and fifth groups, the map of common colon diseases was drawn according to their biopsy points.

3.3. Statistical Analysis

Spatial autocorrelation of colon biopsies was calculated using the Moran's Index (MI) in the ArcGIS software version 10.1 (ESRI, Redlands, CA, USA). Spatial autocorrelation is an assessment of correlation between a variable and its spatial location; hence, MI measures spatial autocorrelation based on both feature locations and values simultaneously. MI has values ranged from +1 (meaning strong positive spatial autocorrelation and tendency toward clustering) to -1 (meaning strong negative spatial autocorrelation and tendency toward dispersion) (21).

4. Results

After exclusion of 311 biopsies which were related to unspecific regions, a total of 4815 biopsies from 2663 patients were reviewed within three consecutive years. There were 2592 (53.8%) biopsies taken from 1441 men with a mean age of 41.95 ± 20.06 years and 2223 (46.2%) biopsies obtained from 1222 women with a mean age of 41.57 ± 18.53 years. Normal specimens and abnormal pathology reports were 2034 (42.2%) and 2781 (57.8%) of the total reports, respectively. As previously described, abnormal biopsies were categorized into five major groups. Pathology records were summarized in Table 2. About a half of 259 biopsies in the group 1 were concentrated in the rectum. In this group of about 247 biopsies consistent with adenocarcinoma, 75.9% were gathered in the left colon (distal to splenic flexure) and 24.1% related to the right colon (proximal to splenic flexure) (Table 3). The mean age of those with left colon adenocarcinoma was 53.4 years and the mean age of those with right colon adenocarcinoma was 58.2 years. A total number of 537 specimens were compatible with IBD. While, 48.2% of biopsies were indeterminate colitis (IC), 47.1% and 4.7% were cases of UC and CD, respectively. UC was more common in

Table 1. Pathology Groups and Subgroups According to Lesion Types [a]

Pathology Group	Pathology Subgroups
Neoplastic	
Primary	adenocarcinoma, carcinoma in situ, carcinoid tumor, gastrointestinal stromal tumor (GIST)
Secondary	chronic lymphocytic leukemia (CLL), lymphoma, melanoma, sarcoma, small cell carcinoma, cystadenocarcinoma, squamous cell carcinoma (SCC)
IBD	Crohn's disease, indeterminate colitis, ulcerative colitis
Polyps	
Benign	fibroepithelial, hamartomatous including Peutz-Jeghers syndrome, hyperplastic, inflammatory, lymphoid, mesenchymal, retention
Neoplastic	adenomatous, tubular adenoma, Tubulovillous adenoma, Villous adenoma
Others	cytomegalovirus colitis, diverticulitis, Graft-versus-host disease(GVHD), pneumatosis cystoides intestinalis, pseudomembranous colitis, posttransplant lymphoproliferative disease (PTLD), submucosal lipoma, solitary rectal ulcer
Nonspecific	acute colitis, acute and chronic colitis, acute ischemic colitis, allergic colitis, chronic colitis, glandular atrophy, lymphoid hyperplasia, melanosis coli, ulcer

[a] Abbreviations: IBD, Inflammatory bowel diseases.

the left colon compared to the right colon (66% vs. 34%). CD was evenly distributed throughout the colon (Table 4). In the group 3, there were 53.5% benign polyps and 46.5% of biopsies were neoplastic polyps. Right-sided polyps were 25.1% and 27.6% and left-sided polyps were 74.9% and 72.4% of benign and neoplastic polyps, respectively. Of total benign polyps, 82.5% were belonged to hyperplastic polyps (HP) and among the neoplastic polyps, 92.3% were adenomatous polyps (AP). Distal part of colon was the place where we found 72.3% and 72.7% of HP and AP (Table 5). Map of all colonic biopsies and groups 1, 2, and 3 was plotted (Figure 1). MI was used to measure similarities between biopsy points. The data was summarized in Table 6 and Figure 2.

Table 2. Distribution of Pathology Groups in the Colon Biopsies [a, b]

Location	Pathology Groups					
	1	**2**	**3**	**4**	**5**	**Grand Total**
CC	19 (0.7)	74 (2.7)	61 (2.2)	5 (0.2)	236 (8.5)	395 (14.2)
AA	33 (1.2)	37 (1.3)	84 (3.0)	1 (0.0)	89 (3.2)	244 (8.8)
HF	-	-	8 (0.3)	-	6 (0.2)	14 (0.5)
TR	9 (0.3)	67 (2.4)	53 (1.9)	3 (0.1)	109 (3.9)	241 (8.7)
SF	3 (0.1)	4 (0.1)	7 (0.3)	0.0	6 (0.2)	20 (0.7)
DD	13 (0.5)	73 (2.6)	72 (2.6)	4 (0.1)	119 (4.3)	281 (10.1)
SS	43 (1.5)	53 (1.9)	123 (4.4)	5 (0.2)	117 (4.2)	341 (12.3)
RS	17 (0.6)	72 (2.6)	32 (1.2)	9 (0.3)	87 (3.1)	217 (7.8)
RR	122 (4.4)	157 (5.6)	371 (13.3)	111 (4.0)	267 (9.6)	1028 (37.0)
Total	259 (9.3)	537 (19.3)	811 (29.2)	138 (5.0)	1036 (37.3)	2781 (100.0)

[a] Abbreviations: AA, ascending colon; CC, Cecum; DD, descending colon; HF, hepatic flexure; RR, rectum; RS, rectosigmoid junction; SF, splenic flexure; SS, sigmoid; TR, transverse colon.
[b] Data are presented as No. (%).

Table 3. Distribution Pattern of Neoplastic Biopsies [a, b]

Location	Type of Neoplasm			
	Primary	**Right-vs. Left-Sided CRC, %**	**Secondary**	**Grand Total**
CC	17 (6.6)		2 (0.8)	19 (7.3)
AA	32 (12.4)		1 (0.4)	33 (12.7)
HF	-	24.1	-	-
TR	8 (3.1)		1 (0.4)	9 (3.5)
SF	3 (1.2)		-	3 (1.2)
DD	13 (5.0)		-	13 (5.0)
SS	42 (16.2)	75.9	1 (0.4)	43 (16.6)
RS	17 (6.6)		-	17 (6.6)
RR	115 (44.4)		7 (2.7)	122 (47.1)
Total	247 (95.4)		12 (4.6)	259 (100.0)

[a] Abbreviations: AA, ascending colon; CC, cecum; CRC, colorectal cancer; DD, descending colon; HF, hepatic flexure; RR, rectum; RS, rectosigmoid junction; SF, splenic flexure; SS, sigmoid; TR, transverse colon.
[b] Data are presented as No. (%).

Table 4. Inflammatory Bowel Diseases Distribution in the Colon Biopsies [a, b]

Location	IBD			
	CD	**UC**	**IC**	**Grand Total**
CC	4 (0.7)	31 (5.8)	39 (7.3)	74 (13.8)
AA	3 (0.6)	20 (3.7)	14 (2.6)	37 (6.9)
HF	-	-	-	-
TR	3 (0.6)	33 (6.1)	31 (5.8)	67 (12.5)
SF	-	2 (0.4)	2 (0.4)	4 (0.7)
DD	5 (0.9)	34 (6.3)	34 (6.3)	73 (13.6)
SS	3 (0.6)	26 (4.8)	24 (4.5)	53 (9.9)
RS	2 (0.4)	38 (7.1)	32 (6.0)	72 (13.4)
RR	5 (0.9)	69 (12.8)	83 (15.5)	157 (29.2)
Total	25 (4.7)	253 (47.1)	259 (48.2)	537 (100.0)

[a] Abbreviations: AA, Ascending colon; CC, cecum; CD, Crohn's disease; DD, descending colon; HF, hepatic flexure; IBD, inflammatory bowel disease; IC, indeterminate colitis; RR, rectum; RS, rectosigmoid junction; SF, splenic flexure; SS, sigmoid; TR, transverse colon; UC, ulcerative colitis.
[b] Data are presented as No. (%).

Table 5. Polyps Distribution in the Colon [a, b]

Location	Polyps		
	Benign	**Neoplastic**	**Grand Total**
CC	28 (3.5)	33 (4.1)	61 (7.5)
AA	44 (5.4)	40 (4.9)	84 (10.4)
HF	6 (0.7)	2 (0.2)	8 (1.0)
TR	26 (3.2)	27 (3.3)	53 (6.5)
SF	5 (0.6)	2 (0.2)	7 (0.9)
DD	34 (4.2)	38 (4.7)	72 (8.9)
SS	54 (6.7)	69 (8.5)	123 (15.2)
RS	21 (2.6)	11 (1.4)	32 (3.9)
RR	216 (26.6)	155 (19.1)	371 (45.7)
Total	434 (53.5)	377 (46.5)	811 (100.0)

[a] Abbreviations: AA, ascending colon; CC, Cecum; DD, descending colon; HF, hepatic flexure; RR, rectum; RS, rectosigmoid junction; SF, splenic flexure; SS, sigmoid; TR, transverse colon.
[b] Data are presented as No. (%).

Table 6. The Moran's Index, Z-Score and P Value of Total, Neoplastic, IBD and Polyps Groups

Group	Moran's Index		Z-Score		P Value	
	By Age	**By Sex**	**By Age**	**By Sex**	**By Age**	**By Sex**
All groups	+0.03	0	+23.91 [a]	-0.64 [b]	0 [c]	0.51
Neoplastic	-0.01	0	-0.55 [b]	-0.3 [b]	0.58	0.76
IBD	+0.02	-0.03	+2.49 [d]	-2.32 [d]	0.01 [c]	0.02 [c]
Polyps	0	+0.05	+0.76 [b]	+9.36 [a]	0.44	0 [c]

[a] There is less than 1% likelihood that this clustered pattern could be the result of random chance.
[b] The pattern of attributes appears to be arranged randomly and independently in space.
[c] Statistically significant(P-value<0.05) IBD, Inflammatory bowel diseases.
[d] There is less than 5% likelihood that this clustered pattern could be the result of random chance.
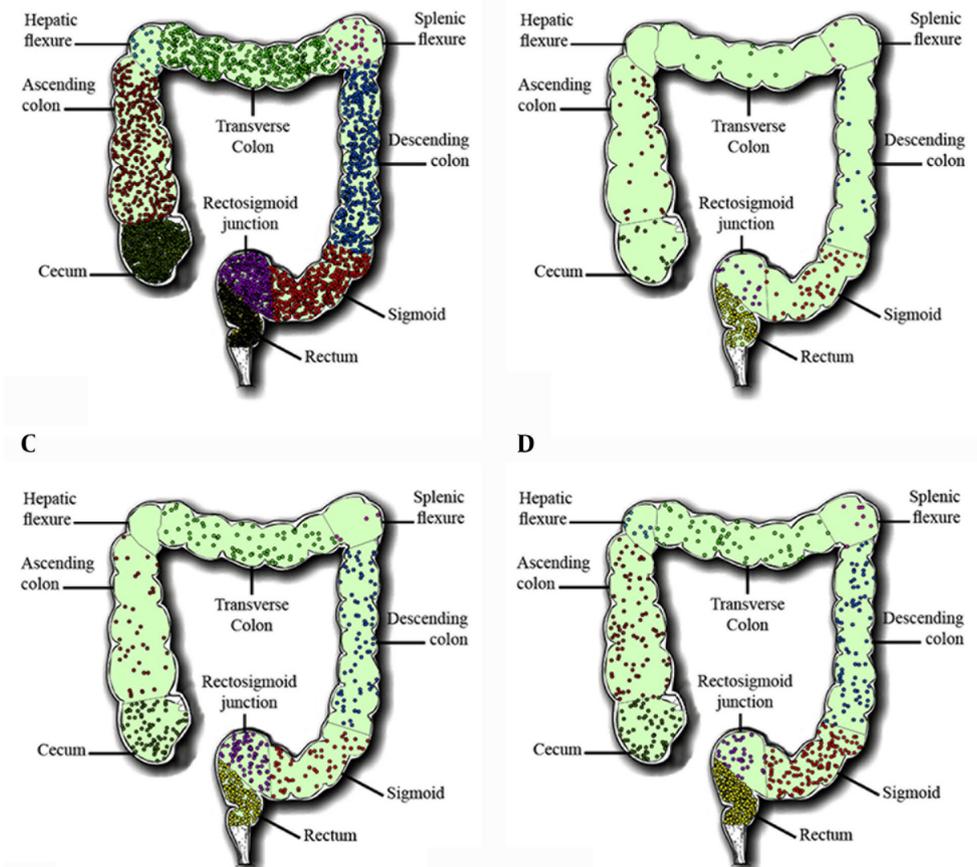
Figure 1. A, Map of total colonic lesions using geographic information system; B, map of neoplastic lesions using geographic information system; C, map of inflammatory bowel diseases lesions using geographic information system; D, map of polyps using geographic information system.
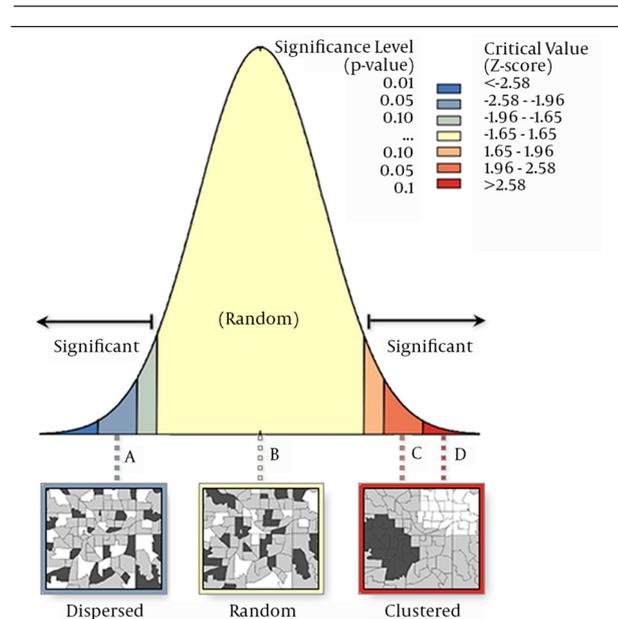
Figure 2. A, Z-Score of the Moran's index of inflammatory bowel diseases lesions by gender; B, Z-score of the Moran's index of all groups except those mentioned in A, C and D. C, Z-score of the Moran's index of IBD lesions by age; D, Z-score of the Moran's index of all groups lesions by age and polyps by gender.

5. Discussion

GIS has been used to design governmental policies around the world to improve health care services (13). Application of GIS to show the human body lesions in gastrointestinal system is rare. In a recent study in which GIS was used to improve the performance of transanal endoscopic microsurgery to locate and remove rectal lesions, the authors concluded that GIS is a valuable tool for demonstration of anatomic features of any type and may illuminate disease patterns and therapeutic procedures (19, 20). By using GIS and the schematic map of colon, the present cross-sectional retrospective study introduced a new model for distribution of colon lesions. While other studies focused on descriptive and statistical analysis of colonoscopic data, the current study concentrated on the thematic mapping of lesions in colon. Besides, our study estimated the concentration or density of different colonic lesions by gender and age of patients based on spatial statistics. The distribution pattern of colon lesions must be considered in endoscopic maneuvers and surgical procedures. Our study showed that the prevalence of distal or left-sided CRC (Lt-CRC) lesions was higher than the proximal or right-sided CRC (Rt-CRC) lesions by threefold. CRC as the third most frequent cancer in males and the second in females in the world, has shown a change in distribution pattern in colon (22). During the recent decades, growth in the incidence of Rt-CRC was accompanied by decreasing or stable incidence of Lt-CRC (1-5). Separation of CRC into two parts with splenic flexure as a boundary in aetiological studies was first suggested by Jensen in early 1980s (23). Since then many clinical, epide-

miological and molecular investigations supported the two-colon paradigm originated from the fact that Rt-CRC and Lt-CRC have different embryologic origins (24). This difference may influence the developmental and biological variations in Rt-CRC and Lt-CRC and also genetic vulnerabilities to carcinogens (25, 26), while it alters the clinical outcome and prognosis of CRC. The prognosis of Rt-CRC is relatively worse than Lt-CRC (27, 28). Recently some researchers recommended gradual changes in tumor molecular features from rectum to ascending colon rather than proposed abrupt changes at splenic flexure (29). In Iranian population, CRC is among the top five common cancers (15). In addition, a significant increase in the incidence of CRC is seen in the city of Shiraz since 1980s (30). Apart from patients with positive family history of CRC, proximal shifting of CRC was not seen in the Iranian population (30-32). In the current study, about three-fourths of both benign and neoplastic polyps were found in the distal part of colon. According to our results, over 80% of benign polyps were HP and up to 72% of them were distal types. On the other hand, about 90% of biopsies showing neoplastic polyps were correlated with AP and 72% of APs were located in the distal colon. Previous studies in the Iranian population were correlated with these findings, whereas most polyps were left-sided and the most common type of polyps was AP (33, 34). Left-sided location of polyps was also an independent risk factor of high-grade dysplasia (35, 36). Qumseya et al. reported that the proximal polyps were more associated with dysplasia (7). Previously it was declared that approximately 90% of HPs located in the distal colon had a low risk of malignancy (37, 38), but an intermediate risk of proximal neoplasia was seen in patients with distal HPs compared to those with distal adenomas or without distal polyps (39). In our study, unlike the uniform distribution pattern of CD in the colon, UC was tended to be more distal. Opposed to patients with ulcerative proctitis, patients with pancolitis, left-sided UC or those with more proximal diseases were at higher risk of developing CRC (8-11). Ekbom et al. evaluated the risk of CRC in CD and mentioned that patients with colonic Crohn's had a risk ratio of 5.6 for developing CRC (12). This study had a number of limitations. First, our study did not explain the exact location of colon lesions and did not evaluate the size of lesions along the colon. Second, about a half of biopsies consistent with IBD were related to IC and did not have definite pathologic diagnosis. The last one was limitation in gathering data. The authors did not have access to computerized data and all collected data were entered by hand. Our study showed that left-sided lesions are still more common in the Iranian population. About three-fourths of neoplastic lesions and polyps and two-thirds of specimens consistent with IBD lesions were from the left colon. Besides, surveying right colon is as important as the distal part, which necessitates total colonoscopy. We demonstrated that GIS could be valuable software for presentation of different lesions all over the human body

systems. In addition to analytic and statistical abilities of GIS, two-dimensional maps display pathologic lesions completely at a glance.

Authors' Contributions

Mohammad Hadi Imanieh: analysis and interpretation of data. Ali Goli: conception and design, analysis and interpretation of data. Mohammad Hossein Imanieh: all parts of the investigation. Bita Geramizadeh: analysis and interpretation of data.

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