Frequency of and risk factors for the surgical resection of nonmalignant colorectal polyps: a population-based study

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Background and study aims: The management of patients with colon polyps who are referred to surgery remains uncharacterized in a population-based setting. The aims of this study were to determine the frequency, risk factors, and outcomes of patients referred for surgical resection of colorectal polyps.

Patients and methods: All patients who underwent a colonoscopy for positive fecal occult blood test in the setting of a population-based colorectal cancer screening program in France between 2003 and 2012 were analyzed. The primary outcome was the proportion of patients undergoing colorectal surgery for polyps without invasive carcinoma. Logistic regression analysis was applied to identify risk factors for surgical resection.

Results: Among 4251 patients with at least one colorectal polyp, 175 (4.1 %) underwent colorectal surgery. Risk factors for surgery included size, proximal polyp location, advanced histology (villous or high grade dysplasia), the endoscopy center, and colonoscopy performed during the first half of the study period. Subgroup analysis of 3475 colonoscopies performed by 22 endoscopists who performed at least 50 colonoscopies during the study period, identified the endoscopist as an additional risk factor. The adjusted proportions of referrals to surgery ranged from 0 to 46.6 % per endoscopist for polyps ≥ 20 mm (median 20.2 %). Overall, surgical complications occurred in 24.0 %, and one patient died following surgery (0.5 %). None of the 175 patients who underwent surgery were referred to a tertiary endoscopic center prior to surgery.

Conclusions: In this population-based study, 4.1 % of patients with nonmalignant polyps were referred for surgical resection. The endoscopist was one important factor that was associated with surgical referral. To further decrease the proportion of inappropriate surgery in patients, endoscopists should refer their patients with large or difficult polyps to expert endoscopists prior to surgery.

Introduction

Colonoscopy is thought to have a major protective effect against colorectal cancer (CRC) by detecting and removing precancerous lesions. Cohort and population-based studies have estimated that colonoscopy with polypectomy could significantly reduce CRC mortality and incidence [1–3]. The vast majority of polyps detected during colonoscopy do not represent a significant challenge for an appropriately trained and skilled endoscopist. However, a small proportion of polyps are not amenable to standard techniques of endoscopic resection [4, 5].

Risk factors associated with the technical inability to resect colorectal polyps include large size, flat or sessile morphology, challenging locations behind haustral folds, and ileocecal valve involvement [4, 5]. Polyps that are deemed unresectable via endoscopy are generally referred for surgical resection. However, the use of advanced polypectomy and endoscopic mucosal resection techniques by an advanced endoscopist has been effective and safe for the majority of patients who are referred to a tertiary interventional endoscopy center (TIEC) for large (≥ 2 cm) or difficult polyps [6–15]. Moreover, repeat colonoscopy performed by an expert endoscopist for patients directly referred to a surgeon considerably decreases the need for surgery [16, 17].

The increased implementation of CRC screening programs internationally should lead to an increased detection of large or difficult colorectal polyps. Inexperience or the reluctance of endoscopists to refer patients to a TIEC may contribute to an increasing number of inappropriate referrals to surgery. However, little is known about the management of colon polyps and particularly

about the frequency of referral to surgery in community practice. Therefore, the primary aims of this study were to assess both the frequency of surgical resection for colorectal polyps that lack invasive carcinoma by analysis of a 10-year population-based screening program and the potential risk factors for surgery, including the role of endoscopists. The secondary outcomes included the 28-day morbidity and mortality rates of surgery.

Methods

Study population

Ille-et-Vilaine is one of the first administrative areas in France to implement the national CRC screening program using the fecal occult blood test (FOBT; Hemoccult II; Beckman Coulter Inc., Villepinte, France). The characteristics of this screening program have been reported previously [18, 19]. Individuals aged between 50 and 74 years and with an average risk of CRC and no contraindications for colonoscopy were invited to undergo the test every 2 years. The population in the area included approximately one million inhabitants during the study period. The participation rate varied from 41.5% to 51.5% during the six consecutive screening rounds organized from February 2003 to December 2012. A positive FOBT was followed by a colonoscopy in more than 90% of cases at each round, and 8713 index colonoscopies were performed during this period. The colonoscopy findings were prospectively included in the ADECI$_{35}$ (Association pour le dépistage des cancers en Ille-et-Vilaine) database.

The CRC screening program was declared and approved by the CNIL "Commission Nationale de l'Informatique et des Libertés" in August 2002 (No. 812571). The research was approved by the CCTIRS "Comité Consultatif pour le Traitement de l'Information en matière de Recherche dans le domaine de la Santé."

Study design

All patients with at least one polyp were included in the study, independent of the completion status of the colonoscopy. Normal colonoscopies (n = 3546), colonoscopies that identified invasive neoplasms (carcinoma with infiltration beyond the muscularis mucosae) (n = 561), procedures involving nonretrieved polyps (n = 316), and patients living outside the administrative area (n = 39) were excluded.

Polyp characteristics

The size of the polyps, as assessed by the endoscopist, was categorized as < 10 mm, 10 – 19 mm, or ≥ 20 mm. Polyps adjacent or distal to the splenic flexure were considered distal, and all other polyps were considered proximal. According to their appearance, the lesions were defined as sessile, pedunculated, flat, or tumor-like. Histopathology records were prospectively obtained from the pathologists. The polyps were categorized as adenomas, hyperplastic polyps, advanced serrated polyps, or other. The advanced serrated polyps corresponded to either sessile serrated polyps/adenomas, traditional serrated adenomas, or mixed polyps. The adenomas were classified as tubular, tubulovillous, or villous, with either low grade or high grade dysplasia.

Patient characteristics

The patients' age and sex were recorded. Because findings of the index colonoscopy and those of a potential referred colonoscopy could have been pooled and not separated in the ADECI database, manual searching was done to identify potential medical records in the database of the endoscopy center at the University Hospital in Rennes, which acts as the TIEC in the area. This search included patients who had one polyp ≥ 20 mm at colonoscopy, regardless of whether the patients underwent surgery.

Colonoscopy characteristics

The following data were collected from the database: date of the colonoscopy and the endoscopic center at which the procedure was performed. Cecal intubation was recorded at the time of the colonoscopy and was based on the endoscopists' assessment of the extent of intubation based on anatomical landmarks. In cases of multiple polyps (> 1), the colonoscopy findings were graded according to the largest polyp.

Endoscopist characteristics

The following parameters relating to the endoscopists were collected from the database: birth date; age at time of the first colonoscopy performed in the screening program setting; professional setting (public, private or both); the number of normal colonoscopies performed (defined as colonoscopies without polyps or cancer); the number of colonoscopies with invasive cancer; and the total number of colonoscopies performed per year of practice in the screening program. The total number of colonoscopies was defined as the sum of the normal colonoscopies and the colonoscopies with at least one polyp and/or cancer. The adjusted cecal intubation rate was defined based on the total number of colonoscopies without invasive cancer per endoscopist. Finally, the detection rate of polyps, or adenomas, was defined as the proportion of colonoscopies with at least one polyp or one adenoma out of the total number of colonoscopies per endoscopist.

Surgery characteristics

All medical records of the patients who underwent surgery were retrospectively reviewed. The following data were collected: the date of surgery; the use of an open or laparoscopic method; postoperative adverse events, which were classified according to the Clavien – Dindo classification [20]; and the length of hospital stay. Endoscopists, surgeons, and general practitioners were contacted by telephone to collect data when medical records were not available. Data were available for all patients who underwent surgery.

Statistical analysis

The primary outcome measures were the proportion of patients referred to surgery for nonmalignant polyps and the potential risk factors for surgical resection. The quantitative data are expressed as the means (SD), and the qualitative data are expressed as numbers and percentages.

For the univariable analysis, each variable was tested for association with surgical resection. For polyp characteristics, the two groups (surgically resected polyps vs. endoscopically resected polyps) were compared using the chi-squared test or Fisher's exact test (according to the application conditions) for the categorical variables and using Student's *t* test or the Wilcoxon rank-sum test (according to the application conditions) for the continuous variables. For the patient and colonoscopy characteristics, the two groups (surgery vs. no surgery) were compared by logistic regression (one model per characteristic).

To identify the polyp and patient features and the colonoscopy factors associated with surgical resection, a multiple logistic regression was applied on a per-patient analysis. The polyp-related

Table 1 Characteristics of polyps, patients, and colonoscopies.

Variable	Total cohort, n	No surgery, n (%)[1]	Surgery, n (%)[1]
Polyp characteristics	**8663**	**8449 (100.0)**	**214 (100.0)**
Size, mm			
< 10	6464	6432 (76.1)	32 (15.0)
10 – 19	1463	1435 (17.0)	28 (13.1)
≥ 20	736	582 (6.9)	154 (72.0)
≥ 30	291	174 (2.1)	117 (54.7)
≥ 40	96	30 (0.4)	66 (30.8)
≥ 50	45	11 (0.1)	34 (15.9)
Location			
Right colon	1982	1935 (22.9)	47 (22.0)
Transverse colon	773	767 (9.1)	6 (2.8)
Left colon	924	893 (10.6)	31 (14.5)
Rectum + sigmoid colon	4967	4837 (57.2)	130 (60.7)
Unknown	17	17 (0.2)	0
Morphology			
Flat	702	687 (8.1)	15 (7.0)
Sessile	5101	4996 (59.1)	105 (49.1)
Pedunculated	2330	2244 (26.6)	86 (40.2)
Tumor-like	3	2 (0.0)	1 (0.5)
Unknown	527	520 (6.2)	7 (3.3)
Histology			
Hyperplastic	2508	2503 (29.6)	5 (2.3)
Adenoma			
Tubular	3394	3369 (39.9)	25 (11.7)
Tubulovillous	2334	2178 (25.8)	156 (72.9)
Villous	85	64 (0.8)	21 (9.8)
Advanced serrated	127	123 (1.5)	4 (1.9)
Various	157	156 (1.8)	1 (0.5)
Unknown	58	56 (0.7)	2 (0.9)
Dysplasia			
High grade or intramucosal carcinoma	2030	1890 (22.4)	140 (65.4)
Low grade or no dysplasia	6633	6559 (77.6)	74 (34.6)
Patient or colonoscopy characteristics	**4251**	**4076**	**175 (100.0)**
Age, years			
50 – 54	741	716 (17.6)	25 (14.3)
55 – 59	819	790 (19.4)	29 (16.6)
60 – 64	942	900 (22.1)	42 (24.0)
65 – 69	852	809 (19.8)	43 (24.6)
70 – 74	897	861 (21.1)	36 (20.6)
Sex			
Women	1640	1566 (38.4)	74 (42.3)
Men	2611	2510 (61.6)	101 (57.7)
Screening round[2]			
1, 2, 3	2875	2738 (67.2)	137 (78.3)
4, 5, 6	1376	1338 (32.8)	38 (21.7)
Endoscopy center			
1	1331	1286 (31.6)	45 (25.7)
2	738	717 (17.6)	21 (12.0)
3	461	439 (10.8)	22 (12.6)
4	312	283 (6.9)	29 (16.6)
5	325	311 (7.6)	14 (8.0)
6	250	241 (5.9)	9 (5.1)
7	207	187 (4.6)	20 (11.4)
8	627	612 (15.0)	15 (8.6)
Complete colonoscopy			
Yes	4173	4004 (98.2)	169 (96.6)
No	78	72 (1.8)	6 (3.4)
Number of polyps			
1	2192	2089 (51.3)	103 (58.9)
2	1007	975 (23.9)	32 (18.3)
≥ 3	1052	1012 (24.8)	40 (22.9)
Largest polyp size, mm			
< 10	2492	2480 (60.8)	12 (6.9)
10 – 19	1087	1066 (26.2)	21 (12.0)
≥ 20	672	530 (13.0)	142 (81.1)
≥ 30	274	161 (3.9)	113 (64.6)
≥ 40	92	27 (0.7)	65 (37.1)
≥ 50	43	9 (0.2)	34 (19.4)
Largest polyp morphology			
Flat	276	264 (6.5)	12 (6.9)
Sessile	2100	2019 (49.5)	81 (46.3)
Pedunculated	1677	1600 (39.3)	77 (44.0)
Tumor-like	2	1 (0.0)	1 (0.6)
Unknown	196	192 (4.7)	4 (2.3)
Largest polyp location			
Right colon	717	681 (16.7)	36 (20.6)
Transverse colon	324	319 (7.8)	5 (2.9)
Left colon	393	371 (9.1)	22 (12.6)
Rectum + sigmoid colon	2806	2694 (66.1)	112 (64.0)
Unknown	11	11 (0.3)	0
Largest polyp histology			
Hyperplastic	934	934 (22.9)	0
Adenoma	3126	2958 (72.6)	168 (96.0)
Advanced serrated	71	67 (1.6)	4 (2.3)
Various or unknown	120	117 (2.9)	3 (1.7)
Largest polyp dysplasia grading			
High grade or intramucosal carcinoma	823	707 (17.3)	116 (66.3)
Low grade or no dysplasia	3428	3369 (82.7)	59 (33.7)

[1] Percentages are column percentages.
[2] Screening rounds 1, 2, and 3 = study period 2003 – 2009; screening rounds 4, 5, and 6 = study period 2009 – 2013.

factors considered the largest polyp. Odds ratios (ORs) and the corresponding 95% confidence intervals (CI) were used to express the association between the studied variables and the outcome.

To investigate the influence of the endoscopist, a subgroup analysis was performed on 3475 colonoscopies performed by 22 endoscopists who performed at least 50 colonoscopies during the study period. The "endoscopist" variable was introduced into the multiple logistic regression after assessing the effect of polyp and patient characteristics. The endoscopist with the highest proportion of referrals to surgery was used as the reference. To assess variability in the frequency of referral to surgery between endoscopists, adjusted surgery proportions and the corresponding 95%CIs for each endoscopist were calculated from the logistic regression. These were computed for each lesion category (≥ 1 polyp, ≥ 1 adenoma, and ≥ 1 polyp ≥ 20 mm). Adjusted proportions of referrals to surgery for any polyp were then compared between two groups of endoscopists defined by the probability of referral to surgical resection: significantly lower or not significantly lower than that of the highest one (i. e. those with an OR significantly < 1, or not, in the logistic regression). The other endoscopist characteristics were also compared between these two groups.

All the analyses were performed using the statistical software program SAS version 9.3 (SAS Institute Inc., Cary, North Carolina, USA). Statistical significance was defined as $P \leq 0.05$.

Results

Characteristics of the study set

The study set included 4251 patients, 8663 polyps that were endoscopically or surgically removed, and 86 endoscopists who each performed between 1 and 320 (median 12.5) colonoscopies with at least one polyp. The characteristics of the polyps, patients, colonoscopies, and endoscopists are shown in **Table 1** and **Table e2** (available online). The patients included 2611 men and 1640 women. The mean age was 62.9 (7.1) years.

Proportion of referral to surgery

Of the 8663 noncancerous polyps, 214 were surgically resected in 175 patients. The proportion of patients who underwent surgery was 4.1 % (175 of the 4251 patients with at least one polyp at colonoscopy), regardless of the pathological features of the polyps. Four patients underwent surgery for nonadenomatous polyps, which were advanced serrated polyps ranging from 10 to 30 mm in size. The observed surgery proportion was 0.5 % for patients with polyps < 10 mm in size, 1.9 % for polyps of 10 – 19 mm, and 21.1 % for polyps ≥ 20 mm. Among the latter category, the proportion of surgery increased to 41.2 %, 70.7 %, and 79.1 % for those with polyps ≥ 30, ≥ 40, and ≥ 50 mm, respectively.

Among the 672 patients with at least one polyp ≥ 20 mm at colonoscopy, manual searching identified nine (1.3 %) patients who had been referred by their endoscopist to the academic endoscopy center for the endoscopic removal of large polyps. The endoscopic removal of polyps was completed in all nine cases and none of these nine patients was referred to surgery. Inversely, none of the 175 patients who underwent surgery had been referred to this TIEC.

Risk factors for referral to surgery

Significant effects were identified for the following characteristics of the largest polyp found at colonoscopy: size, location, and histology (villous component and high grade dysplasia). Among the procedure characteristics, the endoscopy center and the screening round during the study period were identified (**Table 3**). The proportion of referrals to surgery was lower during 2009 – 2013 than during 2003 – 2009 (2.8 %, and 4.8 %, respectively). Among the six factors identified by logistic regression, a polyp size ≥ 20 mm had the strongest weight (OR 28.0, 95 %CI 14.1 – 55.8; $P < 0.0001$).

Subanalysis of endoscopists performing ≥ 50 colonoscopies

This subgroup analysis included 3475 patients with at least one polyp at colonoscopy performed by 22 endoscopists (a median of 158 colonoscopies per endoscopist) (**Table e2** and **Table e4**). The multiple logistic regression analysis found the same six risk factors as those identified from the total population (**Table 5**). However, when the endoscopist was entered into the model, the screening round and the endoscopy center were no longer significant, whereas the endoscopist was an important risk factor for referral to surgical resection **Table e6** available online). When compared with the endoscopist who had the highest proportion of referrals to surgery, the ORs ranged from 0.02 to 0.96 for the 20 other endoscopists (the OR could not be calculated for endoscopist T, who did not refer any patient to surgery) (**Table e6** available online). When the characteristics of the 12 endoscopists whose upper limit of CI for ORs was < 1 were compared with the characteristics of the 10 others, the polyp detection rates and the adenoma detection rates did not differ between the two groups of endoscopists (**Table e7** available online). The median values of individual endoscopist-adjusted proportions of referral to surgery were 3.7 % (0 to 10.2 %), 4.7 % (0 to 12.8 %), and 20.2 % (0 to 46.6 %), for colonoscopies with at least one polyp, at least one adenoma, or at least one polyp ≥ 20 mm, respectively.

Surgical outcomes

Among the 175 patients who underwent surgery, 101 (57.7 %) were male and 74 (42.3 %) were female. There was no difference in the mean age between the women (62.7 [6.9] years) and men (62.8 [6.8] years) ($P = 0.15$). Open surgery was performed in 49 patients, laparoscopic surgery was performed in 90 patients, transanal excision surgery was performed in 22 patients, and laparoscopic surgery converted into open surgery was performed in 14 patients. The median length of hospital stay was 8 days (interquartile range 6 – 9 days).

The overall complication rate was 24.0 % (42/175) and consisted mostly of postoperative pain and transit dysfunction (**Table e8** available online). According to the Clavien–Dindo classification for postoperative adverse events [20], 40.5 % (17/42) of the events were Grade I, 26.2 % (11/42) were Grade II, 21.4 % (9/42) were Grade III (3 Grade III-a, 6 Grade III-b), and 9.5 % (4/42) were Grade IV (3 Grade IV-a, 1 Grade IV-b). One patient died 15 days after a segmental colectomy from a massive intra-abdominal hemorrhage related to an anastomotic leak. Five patients were readmitted to hospital, and 10 patients underwent repeat surgery.

Discussion

The present population-based study demonstrated that 4.1 % of patients with at least one polyp and no invasive carcinoma at colonoscopy were managed surgically. To the best of our knowledge, there are no data in the literature regarding the surgical management of colon polyps in a community- or population-based setting.

In the present study, the factors associated with surgery in the multivariable analysis were related to the polyp and colonoscopy features but not to the characteristics of the patients. Among the significant factors related to polyps, size had the strongest weight. Thus, among the 175 patients who were referred to surgery, 81.1 % had a polyp ≥ 20 mm. The proportion of patients undergoing surgery was 21.2 % among patients with polyps ≥ 20 mm and 41.2 % in those with polyps ≥ 30 mm. The fact that having a polyp ≥ 20 mm in size was found to be strongly associated with surgery in the present population-based study is in line with findings from two academic series [21,22]. Although the number of polyps was not a risk factor for surgery by univariable and multivariable analysis, 11 (6.3 %) of the 175 patients who underwent surgery had 5 or more polyps at colonoscopy. The fact that polyp morphology was not a risk factor for surgery in the present study has no explanation. We suspect that the 14 patients who underwent surgery for a pedunculated polyp < 20 mm in size were inappropriately referred to surgery.

Table 3 Univariable and multivariable analyses of potential risk factors for referral to surgery (n = 4251 colonoscopies).

	Univariable analysis			Multivariable analysis		
	Odds ratio	95 % CI	*P* value[1]	Odds ratio	95 %CI	*P* value[2]
Characteristics of the largest polyp found at colonoscopy						
Size, mm						
< 10	Ref		**< 0.0001**			**< 0.0001**
10 – 19	**4.07**	**2.00 – 8.31**		**2.45**	**1.13 – 5.31**	
≥ 20	**55.37**	**30.50 – 100.55**		**28.04**	**14.09 – 55.79**	
Morphology			0.4599			
Location						
Sigmoid colon	Ref		**0.0003**			**< 0.0001**
Cecum	1.61	0.87 – 2.97		**5.23**	**2.45 – 11.15**	
Right colon	1.55	0.90 – 2.66		**4.29**	**2.24 – 8.23**	
Hepatic flexure	1.73	0.68 – 4.42		**3.54**	**1.18 – 10.63**	
Transverse colon	0.47	0.19 – 1.19		1.37	0.50 – 3.74	
Splenic flexure	1.88	0.44 – 8.04		2.00	0.40 – 10.01	
Left colon	**1.78**	**1.06 – 2.99**		**2.21**	**1.22 – 4.01**	
Rectosigmoid junction	**3.67**	**2.11 – 6.37**		**3.03**	**1.57 – 5.87**	
Rectum	1.39	0.90 – 2.13		**2.67**	**1.64 – 4.36**	
Villous component						
None	Ref		**< 0.0001**			**0.0036**
Villous component	**10.46**	**6.77 – 16.16**		**2.33**	**1.32 – 4.10**	
High grade dysplasia or intramucosal carcinoma						
None	Ref		**< 0.0001**			**0.0024**
High grade dysplasia or intramucosal carcinoma	**8.40**	**6.13 – 11.52**		**1.82**	**1.23 – 2.67**	
Adenoma						
None	Ref		**< 0.0001**			0.3345
Adenoma	**10.55**	**4.66 – 23.90**				
Patient and procedure characteristics						
Age			0.4244			
Sex			0.3041			
Screening round[3]						
4, 5, 6	Ref		**0.0024**			**0.0021**
1, 2 ,3	**1.76**	**1.22 – 2.54**		**1.93**	**1.27 – 2.93**	
Center						
2	Ref		**< 0.0001**			**0.0005**
1	1.20	0.71 – 2.02		1.09	0.61 – 1.94	
3	1.71	0.93 – 3.15		1.27	0.64 – 2.53	
4	**3.50**	**1.96 – 6.24**		**2.99**	**1.52 – 5.89**	
5	1.54	0.77 – 3.06		1.67	0.77 – 3.61	
6	1.28	0.58 – 2.82		1.09	0.45 – 2.63	
7	**3.65**	**1.94 – 6.88**		**3.64**	**1.73 – 7.64**	
8	0.84	0.43 – 1.64		1.11	0.53 – 2.33	
Complete colonoscopy			0.2885			
Number of polyps at colonoscopy			0.1138			

The significant results are in bold.
[1] Logistic regressions. One model for each potential risk factor, including only the potential risk factor.
[2] Logistic regression. The model included the 7 significant variables tested in the univariable analysis.
[3] Screening rounds 1, 2, and 3 = study period 2003 – 2009; screening rounds 4, 5, and 6 = study period 2009 – 2013

One of the main findings in the present study was the wide variability in the proportion of referrals to surgery among the 22 endoscopists included in the subgroup analysis. Although such a wide variability has been suspected previously, no study, until now, has demonstrated that the individual endoscopist was an important risk factor for referral to surgery. Thus, the proportions of referral to surgery adjusted for polyp characteristics varied among endoscopists from 0 to 10.2 % for polyps of any size (median 3.7 %) and from 0 to 46.6 % for polyps ≥ 20 mm (median 20.2 %). The general consensus is that the factors associated with decision making for endoscopic vs. surgical management are unclear. A recent online video-based survey highlighted a wide variability among 154 American physicians in the assessment and endoscopic management of complex colon polyps [23]. These factors, in conjunction with limited expertise in complex polypectomy, may result in benign complex colon polyps being referred inappropriately for surgical removal; specialists in complex polypectomy were less likely to recommend the surgical removal of adenomas [23].

The present results clearly raise the question of the appropriate level of training that should be expected of endoscopists for the removal of colorectal polyps. Guidelines issued by The American Society for Gastrointestinal Endoscopy state that all endoscopists should be able to resect pedunculated or sessile polyps < 2 cm in size [24]. For larger polyps, it would be unreasonable and unnecessary to expect that all endoscopists should become skilled in

Table 5 Univariable and multivariable analyses of potential risk factors for referral to surgery. Subanalysis of the 22 endoscopists who performed at least 50 colonoscopies (N = 3475 colonoscopies).

	Univariable analysis			Multivariable analysis		
	Odds ratio	95 %CI	*P* value[1]	Odds ratio	95 %CI	*P* value[2]
Characteristics of the largest polyp found at colonoscopy						
Size, mm						
< 10	Ref		**< 0.0001**			**< 0.0001**
10 – 19	**3.494**	**1.69 – 7.23**		2.03	0.91 – 4.51	
≥ 20	**47.401**	**25.98 – 86.49**		**23.74**	**11.72 – 48.06**	
Morphology			0.6758			
Location						
Sigmoid colon	Ref		**0.0013**			**< 0.0001**
Cecum	1.83	0.96 – 3.48		**5.74**	**2.55 – 12.89**	
Right colon	**1.81**	**1.03 – 3.18**		**4.95**	**2.49 – 9.84**	
Hepatic flexure	2.15	0.83 – 5.56		**4.46**	**1.43 – 13.84**	
Transverse colon	0.60	0.24 – 1.50		1.68	0.60 – 4.72	
Splenic flexure	2.34	0.54 – 10.14		2.87	0.54 – 15.16	
Left colon	**1.97**	**1.13 – 3.41**		**2.54**	**1.33 – 4.84**	
Rectosigmoid junction	**3.41**	**1.90 – 6.14**		**3.09**	**1.52 – 6.24**	
Rectum	1.47	0.92 – 2.33		**2.64**	**1.54 – 4.53**	
Villous component						
None	Ref		**< 0.0001**			**0.0011**
Villous component	**11.447**	**6.97 – 18.80**		**3.08**	**1.57 – 6.03**	
High grade dysplasia or intramucosal carcinoma						
None	Ref		**< 0.0001**			**0.0095**
High grade dysplasia or intramucosal carcinoma	**7.617**	**5.46 – 10.63**		**1.73**	**1.14 – 2.61**	
Adenoma						
None	Ref		**< 0.0001**			0.7034
Adenoma	**8.937**	**3.94 – 20.28**				
Patient and procedure characteristics						
Age			0.4665			
Sex			0.7111			
Screening round[3‡]						
4, 5, 6	Ref		**0.0040**			**0.0145**
1, 2, 3	**1.827**	**1.21 – 2.75**		**1.81**	**1.13 – 2.92**	
Center						
2	Ref		**< 0.0001**			**0.0005**
1	1.091	0.64 – 1.85		1.00	0.55 – 1.80	
3	1.548	0.83 – 2.89		1.12	0.55 – 2.27	
4	1.511	0.76 – 3.01		**2.79**	**1.41 – 5.53**	
5	**3.284**	**1.84 – 5.86**		1.69	0.78 – 3.69	
6	1.547	0.65 – 3.71		1.76	0.66 – 4.66	
7	**4.807**	**2.49 – 9.29**		**4.09**	**1.85 – 9.03**	
8	1.034	0.35 – 3.06		1.12	0.33 – 3.75	
Colonoscopy						
Complete colonoscopy	Ref		**0.0416**			0.3003
Incomplete colonoscopy	**2.665**	**1.04 – 6.84**				
Number of polyps at colonoscopy			0.2493			

The significant results are in bold.
[1] Logistic regressions. One model for each potential risk factor, including only the potential risk factor.
[2] Logistic regression. The model included the 8 significant variables tested in the univariable analysis.
[3] Screening rounds 1, 2, and 3 = study period 2003 – 2009; screening rounds 4, 5, and 6 = study period 2009 – 2013.

the technique of endoscopic mucosal resection [25]. Therefore, patients with large or difficult polyps should be referred to expert endoscopists working in academic or private centers. The rather small proportion of patients (1.3 %) who were referred to the academic endoscopy center in the present study might illustrate the reluctance of most endoscopists to refer their patients to a colleague working in a TIEC for fear of appearing unskilled. Geographic distance does not seem to be a plausible explanation for referral to surgery rather than to an expert endoscopist in our area. Interestingly, when the characteristics of the 12 endoscopists with the lowest number of referrals to surgery were compared with those of the other 10 endoscopists, the differences were neither numerous nor significant. Neither the polyp detection rates nor the adenoma detection rates differed between the two groups of endoscopists, demonstrating that there was no link between the ability of the endoscopists to detect adenomas and their ability to remove adenomas.

It is noteworthy that the endoscopic removal of polyps was successful in all nine patients who were referred to the academic center, and that none of the 175 patients who underwent surgery

had been referred to the academic center. These findings are in line with those from a recent series of colonoscopies performed in a TIEC for difficult colon polyps [8,12,15,17]. We speculate that the high proportions of surgery for patients with polyps ≥20 mm would have dramatically decreased if more patients had been referred to a TIEC for a second colonoscopy in the present study. Decreasing the proportion of referrals to surgery is a strategy to reduce the risk of death and the risk of postoperative adverse events. Among the 175 patients who underwent surgery in the present population-based study, one patient died postoperatively, and the overall postoperative rate of adverse events was 24.0%. Although the adjusted 28-day mortality has been estimated to be between 4.5% and 5.6% for patients undergoing colectomy [8], a recent series of laparoscopic resections for benign colorectal polyps that were not suitable for endoscopic polypectomy reported a zero mortality rate and morbidity rates that were approximately 20% [26–29]; these morbidity rates are comparable to the findings in the present study.

This study has several limitations. First, it was a retrospective study, although the colonoscopy findings were prospectively registered. Second, it is possible that some patients may have been referred by an endoscopist to a skilled colleague working in a private center; however, our knowledge of the community of endoscopists included in the study leads us to consider this assumption as unlikely. Third, there was no systematic follow-up after colonoscopy; thus, a comparison of the adverse events between endoscopic and surgical removal of polyps was not feasible. Fourth, patient co-morbidities were not assessed in the study. This is a methodological shortcoming because adjustment for co-morbidities was not possible in the logistic regression model, and could have caused bias in parameter estimation. However, it is unclear whether patient co-morbidities affect whether an endoscopist attempts an endoscopic resection or refers a patient to surgery, but we have previously demonstrated from an academic series of colonoscopies that co-morbidities (as assessed by the American Society of Anesthesiologists class, body mass index, or use of antiplatelet medication) were not predictors of surgery for colon polyps [22]. Fifth, although the study population was restricted to colonoscopies following positive FOBT, the generalizability of the results to various indications for colonoscopy seems likely. Sixth, although the generalizability of the results to other areas in France appears likely, the generalizability to other countries with different healthcare organizations is unknown and must be evaluated. In France, only gastroenterologists perform colonoscopies. However, in the video-based survey study previously mentioned, surgeons were more likely than specialists in complex polypectomy to recommend the surgical resection of complex nonmalignant colorectal polyps [23].

In conclusion, this study is the first population-based study to provide information on the prevalence of the surgical removal of nonmalignant colorectal polyps. The study provides new insight into the risk factors for the surgical resection of nonmalignant colorectal polyps, and accurately demonstrates the role of endoscopists in a community-based setting. Overcoming the reluctance of endoscopists to refer patients to experts should be a primary aim in the future. Individual endoscopists' knowledge of their own rates and the awareness of this problem in the community of endoscopists should be encouraged.

Competing interests: None.

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Table e2, e4, e6 – e8

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