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The factors and learning curve associated with complete endoscopic resection of colorectal adenomas

대장 선종의 내시경적 완전 절제에 관련된 요인 및 학습곡선

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서울대학교 대학원

임상의과학과

최지민

Abstract (English)

Introduction: The complete removal of detected adenomatous polyps is important for reducing the incidence and mortality of colorectal cancer, but data on factors affecting the completeness of resection are limited. We aimed to evaluate learning curve of polypectomy as well as the factors affecting the completeness of endoscopic resection.

Methods: We retrospectively studied 1,666 patients who underwent a colonoscopy with at least 1 polypectomy between March 2011 and February 2013. A total of 3,069 adenomatous polyps were included in the analysis. Primary outcomes were polyp characteristics resulting in incomplete resection and the secondary outcome was the level of trainee polypectomy experience resulting in successful complete resection compared to that of the expert.

Results: Of 3,069 adenomatous polyps, 989 (32.2%) were removed by a single expert and 2,080 (67.8%) were removed by seven trainees. In the expert group, piecemeal resection was performed less frequently (2.7% vs. 10.3%; $P < 0.001$) and negative resection margins were obtained more frequently (65.1% vs. 45.2%; $P < 0.001$). In the expert group, larger polyp size ($\geq$10 mm), Is type, and serrated adenoma were associated with incomplete resection. In the fellow group, experience with the procedure was related to resection completeness more so than polyp characteristics. After 300 consecutive polypectomies, the complete resection rate of a

fellow was comparable to that of the expert.

Conclusions: Meticulous attention is critical to ensuring the completeness of endoscopic polypectomies performed by trainee endoscopists before experience of 300 procedures.

Keywords: Adenomatous polyps, polypectomy, colonoscopy, endoscopist, learning curve

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I. INTRODUCTION

Colorectal cancer (CRC) is the third most common malignancy in the world and the fourth leading cause of cancer-related death in Korea (1, 2). About 80% of CRCs originate from adenomatous polyps through the adenoma-carcinoma sequence, and the incidence and mortality of CRC can be reduced by early detection and removal of these premalignant lesions (3-5).

Colonoscopic polypectomy is a cornerstone of effective CRC prevention, but unfortunately, colonoscopy does not prevent all CRC (6, 7). Colon cancers that developed within 5 years of a complete colonoscopy have been termed “interval cancer” (6). Recently, Nishihara et al. reported that screening colonoscopy resulted in reduced mortality from both proximal and distal CRC (8). However, these reductions in incidence and mortality were mainly due to negative colonoscopies, whereas colonoscopy with polypectomy and sigmoidoscopy were unable to reduce the incidence of proximal colon cancer (8). Three plausible reasons (missed polyps, rapid progression of new polyps, and incompletely resected polyps) have been proposed to explain these proximal interval cancers (9-11). The adenoma detection rate (ADR) is the best evidence-based surrogate for the quality of mucosal inspection during colonoscopy, and has been the focus of attempts to decrease the incidence of interval cancer. However, much less attention has been devoted to improving the resection quality of detected polyps. Nearly 25% of interval cancers tended to develop at previous polypectomy segments, and therefore those interval cancers may be attributable to incomplete resection (6). Recently, several articles have focused on identifying factors, such as location, size, morphology, and removal methods, that

influence the incomplete resection rate of adenomatous polyps (9, 12-15). Pohl et al. reported that incomplete polypectomy is not only common (average, 10.1%), but varies substantially among endoscopists (range, 6.5–22.7%), even among expert endoscopists (9). Endoscopic guidelines mandate the complete removal of all colonic polyps if technically feasible, with the exception of small hyperplastic polyps of the rectosigmoid colon (10). The quality of colonoscopy for reducing CRC incidence and mortality is measured not only by the ADR, but also by resection completeness of the detected adenoma. However, little information is available about the rate of incomplete polypectomy of intermediate sized lesions (5–20 mm) in clinical practice and the affecting factors, and there are no guideline addressing the issue of incomplete resection (10). In addition, remarkably little data exist on training programs for colonoscopicpolypectomy and on the number of procedures required to achieve competency in colonoscopic polypectomy.

The aim of the present study was to identify factors affecting the incomplete endoscopic resection rate and to evaluate the experience level of trainees who achieve competence compared with an expert.

II. METHODS

1. Participants

The participants included 7 gastrointestinal fellows who performed more than 300 colorectal polypectomies during training periods and a single expert (expert A; Im JP). All fellow trainees had more than 2 years of experience as gastroenterology specialists, including more than 500 esophagogastroduodenoscopies and 50 colonoscopies per year. Written consent was obtained for their participation in the study.

2. Patients and study design

Between March 2011 and February 2013, 3,883 subjects underwent colonoscopy with at least 1 polypectomy by expert A or 1 of the 7 fellows at Seoul National University Hospital, Korea (Figure 1). We retrospectively reviewed the medical records of these patients and collected data on variables including age, gender, number of adenomas detected, polyp size, location, morphology, histologic diagnosis, resection type (en bloc or piecemeal), and microscopic margin (negative, positive, or not evaluable). Polyps located in cecum, ascending colon, hepatic flexure, or transverse colon were defined as right colon polyps. The evaluation of whether the resection was performed en bloc or piecemeal was based on endoscopist descriptions. We then additionally excluded 1,353 polyps from analysis for the following reasons: adenocarcinoma or neuroendocrine tumor, non-specific change, loss of tissue, and benign polyp (i.e., hyperplastic, inflammatory, hamartomatous, and retention polyps). Ultimately, 1,666 patients with 3,069 adenomatous polyps were included in this study. For the analysis of trainee learning curves,

cases were categorized in chronological order into groups of 100 polyps each. The study was approved by the Ethics Committee of the Seoul National University Hospital (IRB no. H-1303-037-474) and was conducted in accordance with the Declaration of Helsinki.

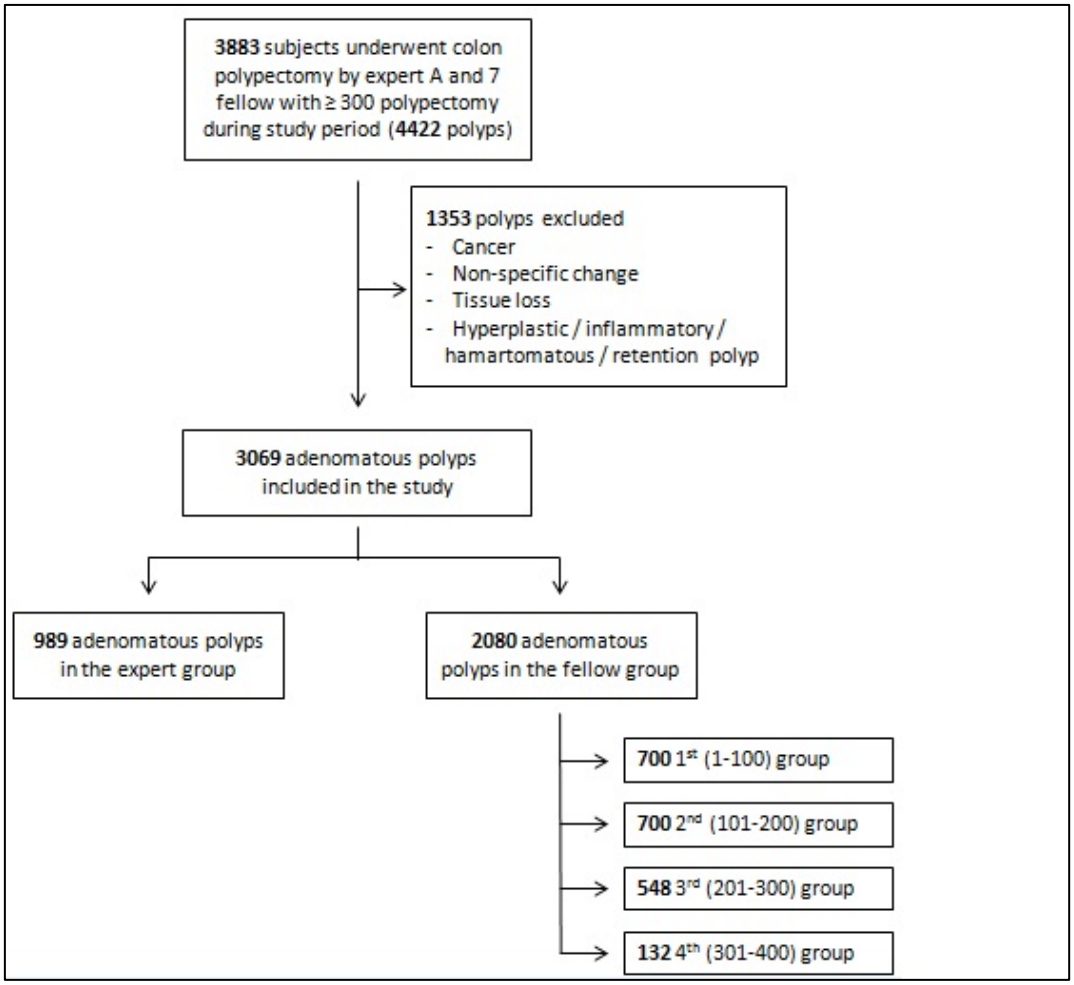


Figure 1. Study enrollment

3. Polypectomy procedure

Colonoscopy was performed using a standard colonoscope (Olympus CF H260AL, Olympus, Tokyo, Japan). Generally, 4 L of polyethylene glycol solution was used for bowel preparation. In cases of sedation colonoscopy, patients were maintained under conscious sedation with 0.05 mg/kg intravenous midazolam and cardiorespiratory function was monitored throughout the procedure. The endoscopists described the size, location, and morphology of each polyp. Polyp size was estimated with open biopsy forceps with a 7-mm span between the 2 jaws when fully opened, and then measured by the pathologist. Once the macroscopic characteristics of the polyp had been documented, endoscopic polypectomy was performed with a saline-epinehprine-indigo carmine (saline 0.9%, epinephrine 0.001%) injection into the submucosal layer using a 23-gauge needle (NM-4U-1; Olympus, Japan) (16). Lesions were then resected by a snare wire with bipolar electrodes using a coagulation current at a setting of 45 W. For lesions of 10 mm or more in diameter, piecemeal resection was planned with a minimal number of pieces. If the excision was considered incomplete macroscopically, hot biopsy forceps electrocauterization or additional bites by biopsy forceps were used for residual lesion removal. Any visible vessels or bleeding sites were routinely coagulated or clipped for the prevention of delayed bleeding.

4. Histopathological diagnosis

The resected specimens were evaluated by an expert gastrointestinal pathologist. Polyps were classified as “neoplastic polyps” and “non-neoplastic polyps.” Neoplastic polyps included the

following lesion types: tubular, tubulovillous, villous adenomas, traditional serrated adenomas, and sessile serrated adenomas/polyps. En bloc resection was defined as the endoscopic resection of an entire lesion in one piece. Resection was considered piecemeal if the lesion was removed in multiple pieces. Microscopic margins were classified into the following 3 categories: negative (R0), positive (R1), and not evaluable (Rx). R0 resection was defined as the absence of adenomatous tissue on both the lateral and vertical margins, whereas R1 resection was defined as microscopic involvement of the resection margin (either lateral or vertical). When the margins were not fully evaluable due to the effects of coagulation or piecemeal resection, the margins were judged to be “not evaluable (Rx).” Complete resection was a pathologic definition applied to en bloc resection with confirmation of adenomatous tissue-free lateral and vertical margins. Because only en bloc resected lesions were included in the analysis, incomplete resection was defined as an R1 resection among en bloc resection cases.

5. Outcome measures

Primary outcomes were factors associated with incomplete resection of adenomatous polyps (in both the expert and fellow group). The secondary outcome was complete resectability according to the cumulative number of procedures, especially in fellow trainees.

6. Statistical analysis

The data were analyzed using SPSS software version 19.0 (SPSS Inc., Chicago, IL, USA). All

data were expressed as the means ± standard deviations (range) or as numbers (percentages). As continuous variables such as age and number of adenomas per patient were distributed non-normally, they were analyzed by a nonparametric approach (Mann-Whitney U-test), while categorical variables were analyzed by the chi-square test or Fisher's exact test as indicated.

A univariate analysis was carried out to evaluate the impact of sex (male vs. female), age (<55 vs. ≥55), polyp size (<10 mm, 10–19 mm, ≥20 mm), location (right-sided colon vs. left-sided colon/rectum), morphology (Ip, Isp, Is), and histology (tubular, tubulovillous/villous, serrated adenoma) on complete resectability of colonic polyps. All variables found to be significant on univariate analysis or thought to be clinically relevant were included in a multivariate statistical model. Odds ratios (ORs) and 95% confidence intervals (CIs) were used to estimate the association between the various factors and the results of colon polypectomy. In addition, procedures performed by fellows were grouped chronologically into groups of 100 cases and further multivariate analysis was conducted to examine the impact of the fellow's experience level on the complete resectability of colonic polyps. A *P*-value < 0.05 was considered statistically significant.

III. RESULTS

1. Patient characteristics

A total of 1,666 patients with eligible polyps were identified during the study period. In 448 (26.9%) patients, procedures were performed by 1 expert endoscopist. Seven fellows performed colon polypectomies in the remaining 1,218 (73.1%) patients. The mean number of adenomas per patient was 1.79 ± 1.33 in the expert-treated group and 1.70 ± 1.33 in the fellow-treated group. There were no differences between the groups with regard to clinical variables such as age, gender, and the number of adenomas per patient (P = 0.066, P = 0.517, and P = 0.094, respectively) (Table 1).

Table 1.Demographic patient characteristics

Characteristics	**Total (n=1666)**		***P* value**
	Expert (n=448)	**Fellow (n=1218)**	
Mean age, y (range)	63.01 ± 8.70 (26-86)	63.81 ± 9.85 (29-93)	0.066
Gender, male	333 (74.3)	886 (72.7)	0.517
No. of adenomas per patient	1.79 ± 1.33 (1-10)	1.70 ± 1.33 (1-11)	0.094

Values are presented as mean ± standard deviation (range) or number of patients with percentages in parentheses.

2. Polyp characteristics

Among the resected specimens, 3,069 were categorized as neoplastic polyps. More than half of the polyps were below 10 mm in diameter, and the size distribution did not differ significantly between the 2 groups (Table 2). There were also no between-group differences in the morphology and histology of the adenomatous polyps. The tumors were more frequently located in the right side of the colon, but the overall distribution did not differ between the 2 groups. The most common morphologic type was Is (48.5% and 46.4%, respectively), while Ip was the least common type (10.1% and 8.5%, respectively). Tubular adenomas were detected in over 90% of all included cases, while less than 5% of all cases were traditional and sessile serrated adenomas. Significantly fewer adenomatous polyps were removed piecemeal in the expert group (2.7% vs. 10.3%, respectively; $P < 0.001$) (Table 3). There was also a significant difference in microscopic margins between the groups, with negative (R0) margins obtained in 65.1% of cases in the expert group compared with 45.2% in the fellow group ($P < 0.001$).

Table 2. Baseline features of colorectal adenomatous polyps

Characteristics	Total (n=3069)		*P* value
	Expert (n=989)	Fellow (n=2080)	
Polyp size, mm			0.080
< 10	784 (79.3)	1573 (75.6)	
10-19	175 (17.7)	429 (20.6)	
≥ 20	30 (3.0)	78 (3.8)	
Location			0.052
Right colon*	577 (58.3)	1136 (54.6)	
Left colon/rectum	412 (41.7)	944 (45.4)	
Morphology			0.084
Is	480 (48.5)	962 (46.4)	
Isp	409 (41.4)	941 (45.2)	
Ip	100 (10.1)	177 (8.5)	
Histology			0.611
Tubular	903 (91.3)	1919 (92.3)	
Tubulovillous/villous	54 (5.5)	97 (4.7)	
Serrated	32 (3.2)	64 (3.1)	

Values are number of patients with percentages in parentheses.

*Right-colon includes the cecum, ascending colon, hepatic flexure, and transverse colon.

Table 3. Results of colorectal adenomatous polyp removal

Results	Total (n=3069)		*P* value
	Expert (n=989)	Fellow (n=2080)	
Resection type			0.000
En bloc	962 (97.3)	1866 (89.7)	
Piecemeal/macroscopically incomplete	27 (2.7)	214 (10.3)	
Microscopic margin			0.000
Negative (R0)	644 (65.1)	940 (45.2)	
Positive (R1)	20 (2.0)	31 (1.5)	
Not evaluable (Rx)	325 (32.9)	1109 (53.3)	

Values are number of patients with percentages in parentheses.

3. Factors associated with incomplete resection

Only cases with en bloc resection were included in the analysis of factors associated with incomplete resection. Cases with Rx resection were also excluded from this analysis. The following results were obtained by performing the univariate analysis. In both groups, patient age and sex did not significantly affect the success rate of polypectomy. In the expert group, significant factors associated with incomplete resection included polyp size, location,

morphology, and histology. The incomplete resection rate increased with increasing polyp size (1.4% vs. 6.5% vs.17.6%; $P < 0.001$). Polyps located in the right-sided colon were more likely to be incompletely resected than those located in the left-sided colon (4.1% vs. 1.0%, respectively; $P = 0.018$). There were also significant differences in incomplete resection rates according to morphologic and histologic type. Incomplete resection rates were higher among Is type polyps than among Ip and Isp type polyps ($P = 0.020$). Incomplete resection rates were also higher in serrated adenomas than in tubular, tubulovillous, and villous adenomas ($P = 0.004$). In the fellow-treated group, however, the only factor associated with incomplete resection that proved significant was histologic type ($P < 0.001$). For both the expert and fellow groups, factors shown to be significant in the univariate analysis or thought to be clinically important, such as polyp size, location, morphology, and histology, were included in a multivariate statistical model. In the multivariate analysis, a polyp diameter of 10–19 mm (OR 5.037; 95% CI, 1.633–15.530; $P = 0.005$), a polyp diameter ≥20 mm (OR 15.361; 95% CI, 2.784–84.749; $P = 0.002$), Is type (OR 18.119; 95% CI, 1.369–239.798; $P = 0.028$), and serrated adenoma (OR 6.165; 95% CI, 1.220–31.140; $P = 0.028$) were found to be independently associated with incomplete resection in the expert group (table 4). As table 5 suggests, histologic diagnosis was the only variable that showed a strong association with incomplete resection in the fellow group (tubulovillous/villous: OR 5.163; 95% CI, 1.170–22.774; $P = 0.030$ vs. serrated: OR 6.030; 95% CI, 1.792–20.297; $P = 0.004$). Larger polyp diameter, right-sided polyp, sessile morphology, and serrated adenoma/polyp also demonstrated a higher tendency towards incomplete endoscopic

resection in this group, but it was not statistically significant.

Table 4. Multivariate analysis of factors associated with incomplete resection of adenomatous polyps (in the expert group)*

Factor	Expert (n=654)	
	Odds ratio (95% CI)†	***P* value**
Size, mm		
<10	1.000 (reference)	
10-19	5.037 (1.633-15.530)	0.005
≥20	15.361 (2.784-84.749)	0.002
Location		
Lt.colon/rectum	1.000 (reference)	
Rt.colon	3.512 (0.901-13.682)	0.070
Morphology		
Ip	1.000 (reference)	
Isp	3.115 (0.265-36.576)	0.366
Is	18.119 (1.369-239.798)	0.028
Histology		
Tubular	1.000 (reference)	
Tubulovillous/Villous	5.146 (0.512-51.701)	0.164
Serrated	6.165 (1.220-31.140)	0.028

*This analysis was performed only for cases with en bloc resection. Cases with Rx resection were excluded from this analysis.

†ORs are adjusted for size, location, morphology, and histology of adenomas.

Table 5. Multivariate analysis of factors associated with incomplete resection of adenomatous polyps (in the fellow group)*

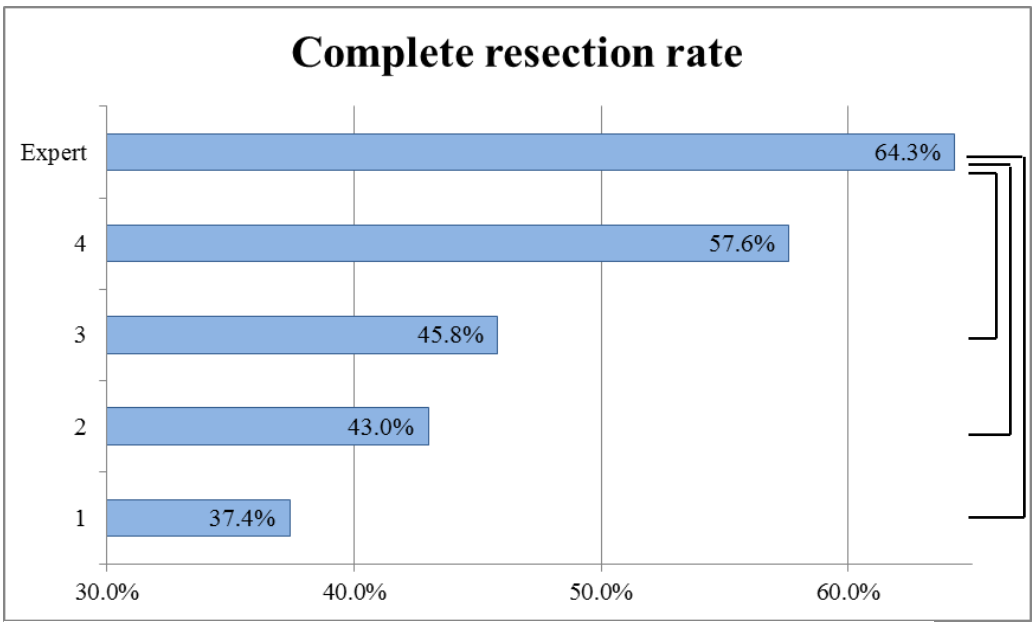
Factor	Fellow (n=916)	
	Odds ratio (95% CI)†	*P* value
Size, mm		
<10	1.000 (reference)	
10-19	1.584 (0.628-3.995)	0.329
≥20	3.517 (0.619-19.996)	0.156
Location		
Lt.colon/rectum	1.000 (reference)	
Rt.colon	1.922 (0.815-4.535)	0.136
Morphology		
Ip	1.000 (reference)	
Isp	5.439 (0.630-46.956)	0.124
Is	6.261 (0.725-54.042)	0.095
Histology		
Tubular	1.000 (reference)	
Tubulovillous/Villous	5.163 (1.170-22.774)	0.030
Serrated	6.030 (1.792-20.297)	0.004

*This analysis was performed only for cases with en bloc resection. Cases with Rx resection were excluded from this analysis.

†ORs are adjusted for size, location, morphology, and histology of adenomas.

4. Endoscopist characteristics and level of experience related to incomplete resection in trainee group

The 7 fellow trainees included in this study comprised 4 male (1,176 polypectomies) and 3 female (904 polypectomies) endoscopists. There was no significant difference in incomplete resection rates according to the sex of the endoscopist (3.0% in males vs. 2.6% in females; P = 0.677). For the purpose of conducting a comparison according to cumulative procedure numbers, procedures performed by fellows were grouped chronologically into 4 groups. Trainees' complete resection rates improved significantly with accumulated experience, from 37.4% to 57.6% (Figure 2). When multivariate analysis was applied, the fourth chronological group demonstrated a similar complete resection rate to that achieved by the expert endoscopist over the course of the study period (OR 0.735; 95% CI, 0.507–1.066; P = 0.105).



	Complete resection rate	Multivariate analysis, OR (95% CI)	P value
Expert	636/989 (64.3%)	1.000 (reference)	
301-400	76/132 (57.6%)	0.735 (0.507-1.066)	0.105
201-300	251/548 (45.8%)	0.472 (0.381-0.585)	0.000
101-200	301/700 (43.0%)	0.409 (0.335-0.500)	0.000
1-100	262/700 (37.4%)	0.324 (0.265-0.397)	0.000

Figure 2. Increased success rate of colon polypectomy according to the number of procedures. The cases were divided chronologically into groups of 100 procedures. The complete resection rate by trainees showed a significant improvement as the experience accumulated. When multivariate analysis was applied, the fourth chronological group demonstrated similar complete resection rate compared with the result of the expert over the study period (*groups 1, 2, and 3 vs. expert, $P < 0.05$).

IV. DISCUSSION

To our knowledge, this is the first study to report that the level of procedure experience of fellow trainees impacts the complete resection rate of adenomatous polyps in addition to polyp features. Additionally, polypectomy completeness was found to gradually improve along with accumulated experience of the polypectomy procedure.

The ability of colonoscopicpolypectomy training to improve polypectomy completeness has not been studied previously, and only a few prior studies examined the characteristics of adenomatous polyps associated with incomplete endoscopic resection (9,12-14).

In this study, we investigated both polyp and endoscopist factors that may significantly affect the outcome of polypectomy procedures. Consistent with prior studies, larger diameter, sessile morphology, and serrated type were found to be associated with an increased risk of incomplete endoscopic removal in the expert group. In terms of the location of the adenomatous polyp, a right-sided location was found to be a significant risk factor for incomplete resection in the expert group by univariate analysis, but this association was not significant after adjustment for other potential risk factors (OR 3.512; 95% CI, 0.901–13.682; P = 0.070). In the fellow group, however, only histologic classification was related to incomplete resection of an adenomatous polyp in the univariate analysis, and it remained significant in the multivariate analysis. In this trainee group, completeness of adenomatous polyp resection depended more on the experience level of the endoscopist than on polyp characteristics. As the number of procedures increased, complete resection was achieved with greater frequency, and fellow trainees were able to

perform polypectomy procedures with similar outcomes to those achieved by the expert, after performing 300 polypectomies. This finding may be attributed to trainees' lack of familiarity with the manipulation of the injection needle, snare, and determination of the cutting plane of the snare, resulting in their inability to secure an adequate margin (17). In this study, such trainee limitations could be overcome by the accumulated experience of at least 300 cumulative procedures. These findings support the need for adequate education and supervision by expert endoscopists for ensuring the completeness of endoscopic procedures and suggest that endoscopic polypectomies might require circumspect attention before a fellow trainee has performed 300 procedures cumulatively (18). These findings also support the notion that endoscopic quality improvement programs should include training for improving polypectomy completeness, not only increasing ADRs, because complete resection rates could be improved by practice.

A high frequency of the right-sided colorectal adenomas (55.8%) was found in the present study compared with other studies. In the recent large, prospective study by Parente et al., 34.4% of the adenomatous polyps were located in the right-sided colon (19). These authors suggested that age of 60 years or older (OR 1.57; 95% CI, 1.28–1.92) and male sex (OR 1.81; 95% CI, 1.47–2.21) were significant predictors of proximal neoplasms. The higher mean age (63.59 years old) and rate of male sex (73.2%) among patients included in our study may have affected the distribution of adenomatous polyps.

In this study, we did not collect follow-up data such as recurrence rate. When considering the

substantial rate of uncheckable (46.7%) or involved margins (1.7%) among resected polyps, however, endoscopic surveillance after polypectomy should be emphasized. As a guideline, patients with high-risk lesions should return to the clinic for a repeat endoscopy with a biopsy of the scar to assess the polypectomy site in 3 to 6 months (20). In previous studies, the rate of residual neoplasia after colonoscopic endoscopic mucosal resection (EMR) was reported to range from 0% to 39%, and additional procedures were needed to complete resections in more than 1 in 10 colonic EMRs (6,17,21). Because the incomplete removal of adenomatous polyps is associated with the occurrence of interval cancer, endoscopists should strive for precise procedures during colonoscopy and polypectomy (6,22). Furthermore, precise pathologic reports of resection margins are also important for determining the surveillance schedule (23).

The strength of this study was the large number of cases both in terms of patients and the number of endoscopists, which improved the study's ability to detect factors associated with incomplete resection of adenomatous polyps and to evaluate the ability of accumulated experience to improve the capability of performing complete resections. Furthermore, this was the first study to suggest the adequate experience of junior trainees required to competently perform polypectomies.

This study had some limitations. First, this was a retrospective study and thus was subject to drawbacks inherent in retrospective analysis. The second limitation of this study was the higher than expected proportion of cases with uncheckable margins (32.9% of the expert group and 53.3% of the fellow group). According to other studies reported in the literature, proportions of

uninterpretable resection margins were 21% using hot biopsy forceps and 24.3–39.8% using an electrosurgical generator (24,25). Uncheckable margins were the result of electrical burn, snaring effect, contraction after excision, and squeezing effect during passage of suction channel. To curtail the uncertainty inherent in the interpretation of uncheckable margins, endoscopists should make an effort to retain wider resection margin surrounding adenomatous tissue. In addition, further study is needed to confirm the long-term outcomes of adenomatous polyps with uncheckable margins.

In conclusion, polyp characteristics such as size, morphology, and histology were important factors for incomplete resection in the expert group. In the trainee group, however, the level of procedure experience was more closely associated with polypectomy outcomes than the characteristics of the polyp. Therefore, trainee endoscopists need to be more attentive to the meticulous procedures involved, and close supervision by an expert endoscopist is necessary to establish the completeness of endoscopic polypectomy before a fellow trainee has experience of 300 procedures.

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초록

서론: 대장암의 발생률과 이로 인한 사망률을 줄이기 위해서는 선종성 용종의 완전 절제가 중요하나 내시경적 완전 절제에 영향을 미치는 요인에 대한 연구는 부족한 실정이다. 이에 내시경적 절제의 완전성에 영향을 미치는 요인 및 용종 절제술의 학습 곡선을 평가하고자 한다.

방법: 2011년 3월부터 2013년 2월 사이에 대장내시경 및 1개 이상의 용종 절제술을 시행받았던 환자 1666에 대해 후향적 연구를 시행하였다. 전체 3069개의 용종성 선종이 분석에 포함되었다. 1차 결과는 내시경적 불완전 절제에 영향을 미치는 용종의 특성으로하였고, 2차 결과는 전문 시술자와 비교하여 성공적인 완전 절제에 요구되는 시술 경험의 수준으로 하였다.

결과: 3069개의 용종성 선종중 989개 (32.2%) 는 한명의 전문 시술자에 의해, 2080개 (67.8%) 는 7명의 전임의에 의해 제거되었다. 전문 시술자군에서 분할 절제율이 유의하게 적었고 (2.7% vs. 10.3%; $P < 0.001$), 음성 절제연이 더 많이 확보되었다 (65.1% vs. 45.2%; $P < 0.001$). 전문 시술자군에서는 큰 직경 ($\geq$10 mm), Is 형, 톱니형 선종이 불완전 절제와 연관을 보였고, 전임의군에서는 용종의 특성보다는 시술 경험의 수준이 절제의 완전성에 더 높은 연관성을 보였다. 전임의군에서 300개 이상의 용종 절제술을 시행하였을 때 완전 절제율이 전문 시술자와 유의한 차이를 보이지 않을 만큼 개선되었다.

결론: 전임의군에서 300개 이상의 용종 절제술을 시행하기 전까지는 내시경적 완전 절제를 위하여 세심한 주의를 기울여야 한다.

주요어: 선종성용종, 용종절제술, 대장내시경, 내시경시술자, 학습곡선

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