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Real-World National Colonoscopy Volume in Korea: A Nationwide Population-Based Study over 12 Years

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Background/Aims: Little is known about the national colonoscopy volume in Asian countries. This study aimed to assess the national colonoscopy volume in Korea over a 12-year period on the basis of a nationwide population-based database. **Methods:** We conducted a population-based study for colonoscopy claims (14,511,158 colonoscopies performed on 13,219,781 patients) on the basis of the Korean National Health Insurance Service database from 2002 to 2013. The 12-year national colonoscopy burden was analyzed according to patient age, patient sex, and healthcare facility type. **Results:** The overall volume of colonoscopy increased 8-fold over the 12-year period. The annual colonoscopic polypectomy rate significantly increased in all patient sex and age groups over the 12-years period (all $p < 0.001$). The yearly colonoscopic polypectomy rate for men was significantly increased compared with that for women (2.3% vs 1.7%, $p < 0.001$) and for the screening-age group compared with that for the young-age group (2.0% vs 1.6%, $p < 0.001$). The yearly colonoscopic polypectomy rate relative to the total colonoscopy volume significantly increased in primary, secondary, and tertiary facilities by 2.4%, 1.9%, and 1.4% during the 12-year period (all $p < 0.001$). In addition, the annual colonoscopy volume covered by high-volume facilities significantly increased by 1.8% in primary healthcare facilities over the 12-year period ($p < 0.001$). **Conclusions:** Healthcare resources should be prioritized to allow adequate colonoscopic capacity, especially for men, individuals in the screening-age group, and at primary healthcare facilities. Cost-effective strategies to improve the quality of colonoscopy may focus

on primary healthcare facilities and high-volume facilities in Korea. (*Gut Liver* 2020;14:338-346)

Key Words: Big data; Colonoscopy; Polypectomy; Population

INTRODUCTION

Colorectal cancer (CRC) is a significant public health problem, as its incidence has been increasing worldwide.^{1,2} Colonoscopy is very effective to reduce the risk of CRC, as most CRCs develop from colorectal adenoma through the adenoma-carcinoma sequence.³⁻⁵ CRC screening rate has been steadily increasing over the years, which significantly prevents the development of CRC.⁶ As a national CRC screening program, most countries, including Korea, use fecal occult blood tests, whereas several Western countries use colonoscopy.^{6,7} The national CRC screening program in Korea coexists alongside opportunistic colonoscopy screening of persons with an average risk of CRC.⁸

In Western countries, limited resources for colonoscopy have been an obstacle in expanding CRC screening program, because only certain specialists are trained to perform colonoscopy and colonoscopic polypectomy.⁹⁻¹² The estimated colonoscopy capacity was sufficient to screen 80% of the eligible U.S. population with fecal test, colonoscopy, or a mix of tests in 2014.⁹ Survey study conducted in the United Kingdom reported that 50% of the endoscopy units provided an adequate colonoscopy service.¹² In some Asian countries such as Korea, Japan, and China, however, colonoscopy burden may be different from that of Western countries because of the excellent accessibility of

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colonoscopy, low cost of colonoscopy, and many available experienced colonoscopists.¹³ Currently, however, no population-based studies have reported the national burden of colonoscopy in Asian countries. A better understanding of national colonoscopy burden may be the first step toward successful implementation of CRC screening program as well as identification of deficits in the current colonoscopy resources in Asian countries.

In this context, we aimed to assess the national burden of colonoscopy according to age, sex, and healthcare facility type, based on a nationwide population-based database in Korea.

MATERIALS AND METHODS

1. Data source and study population

This study is a retrospective nationwide population-based study using the Korean National Health Insurance Service (NHIS) database, which contains all inpatient and outpatient data nationwide since 1989 in Korea. The NHIS database provides a comprehensive healthcare coverage for all Koreans and contains information on claims billed by physicians for services, admissions, diagnoses, procedures, discharge status, and patient demographics.^{14,15} Procedure codes in physician claims databases had a very high level of agreement with data in medical charts.¹⁵

We identified all persons who had at least one colonoscopy in the NHIS physician billing claims database between January 2002, and December 2013. Longitudinal time change in the national burden of colonoscopy was assessed according to age, sex, and healthcare facility type in 12 years. We determined whether patients had undergone colonoscopy without polypectomy (E7660) or with polypectomy (Q7701, single polypectomy;

Q7702, two or more polypectomies; Q7703, endoscopic mucosal resection) using NHIS codes. In this study, colonoscopic polypectomy included endoscopic mucosal resection (Q7703), but endoscopic submucosal dissection was excluded because this procedure is rarely performed and not reimbursed by NHIS. Colonoscopic procedures were analyzed per procedure, as some patients had multiple colonoscopic procedures, whereas an early repeat colonoscopy within 12 months was analyzed per patient.

Study variables were time (2002 to 2013), colonoscopy with or without polypectomy, age groups (young age, <50 years; screening age, 50 to 74 years; and elderly age, ≥75 years), sex, healthcare facility type (primary, secondary, tertiary, and others) and annual volume of facility (high-volume or not). Age group classification was based on the current guidelines that recommend CRC screening for 50- to 75-year-old adults at an average risk for CRC.^{4,5} Primary facility includes a primary outpatient clinic, secondary facility includes a hospital and a general hospital, and tertiary facility includes a specialized general hospital on referral from primary and secondary healthcare facility. Other facility includes dental hospital, nursing hospital, public hospital, and oriental hospital/clinic (traditional medicine hospital/clinics prescribing herbal drug or practicing acupuncture). A high-volume facility was defined as a facility with an annual colonoscopy volume more than 200 cases, because the minimum volume of annual colonoscopy to maintain competency for colonoscopy was 200 cases per year and other universal definition is not available.^{16,17} As a unique situation in Korea, primary healthcare facility includes profit health promotion centers which account for most of high-volume center. As the information used in this study was related only to pseudonyms, the requirement of informed consent was waived. This study

Table 1. National Colonoscopy Burden over the 12-Year Period in Korea

Year	Total volume	Colonoscopy without polypectomy*	Colonoscopic polypectomy*	In-patient polypectomy
2002	264,345	240,167 (90.8)	24,178 (9.1)	9,523 (39.4)
2003	448,051	408,397 (91.1)	39,654 (8.9)	16,016 (40.4)
2004	546,190	487,466 (89.2)	58,724 (10.8)	23,367 (39.8)
2005	751,535	657,790 (87.5)	93,745 (12.5)	35,033 (37.4)
2006	957,534	812,859 (84.9)	144,675 (15.1)	45,369 (31.4)
2007	1,080,359	892,151 (82.6)	188,208 (17.4)	54,583 (29.0)
2008	1,207,613	968,661 (80.2)	238,952 (19.8)	61,273 (25.6)
2009	1,441,564	1,136,222 (78.8)	305,342 (21.2)	75,095 (24.6)
2010	1,601,688	1,226,376 (76.6)	375,312 (23.4)	84,706 (22.6)
2011	1,975,279	1,467,324 (74.3)	507,955 (25.7)	96,464 (19.0)
2012	2,138,150	1,542,315 (72.1)	595,835 (27.9)	103,647 (17.4)
2013	2,098,850	1,474,064 (70.2)	624,786 (29.8)	105,374 (16.9)
Percent change		-2.0	+2.0	-2.4

Data are presented as number or number (%).

*The percent is the proportion of procedures performed each year relative to the total colonoscopy volume.

was approved by the Institutional Review Board of Kyung Hee University Hospital at Gangdong, Seoul, Republic of Korea (IRB number: KHNMC 2018-08-021).

2. Statistical analysis

Descriptive analysis was performed on the entire population during the study period. A generalized linear regression model was applied for sex, age group, and healthcare facility type using the annual proportion of colonoscopy/polypectomy among

the total volume of colonoscopy at each year, compared with those in 2002 as a reference. The trends in the annual colonoscopic polypectomy burden in each age group were assessed by subtraction using the chi-square distribution. All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant. All statistical analyses were conducted using SAS 9.4 statistical software (SAS institute Inc., Cary, NC, USA) and R software packages R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria; <https://www.R-project.org>).

Table 2. National Colonoscopy Burden According to Sex over the 12-Year Period in Korea

Year	Men			Women		
	Total volume	Colonoscopy without polypectomy*	Polypectomy*	Total volume	Colonoscopy without polypectomy*	Polypectomy*
2002	144,252	127,678 (88.5)	16,574 (11.5)	120,093	112,489 (93.7)	7,604 (6.3)
2003	241,827	214,526 (88.7)	27,301 (11.3)	206,224	193,871 (94.0)	12,353 (6.0)
2004	293,264	252,753 (86.2)	40,511 (13.8)	252,926	234,713 (92.8)	18,213 (7.2)
2005	408,158	344,383 (84.4)	63,775 (15.6)	343,377	313,407 (91.3)	29,970 (8.7)
2006	523,894	426,143 (81.3)	97,751 (18.7)	433,640	386,716 (89.2)	46,924 (10.8)
2007	600,398	472,939 (78.8)	127,459 (21.2)	479,961	419,212 (87.3)	60,749 (12.7)
2008	666,918	507,257 (76.1)	159,661 (23.9)	540,695	461,404 (85.3)	79,291 (14.7)
2009	792,350	590,410 (74.5)	201,940 (25.5)	649,214	545,812 (84.1)	103,402 (15.9)
2010	882,390	634,393 (71.9)	247,997 (28.1)	719,298	591,983 (82.3)	127,315 (17.7)
2011	1,115,603	776,992 (69.6)	338,611 (30.4)	859,676	690,332 (80.3)	169,344 (19.7)
2012	1,198,330	804,831 (67.2)	393,499 (32.8)	939,820	737,484 (78.5)	202,336 (21.5)
2013	1,166,880	761,413 (65.3)	405,467 (34.7)	931,970	712,651 (76.5)	219,319 (23.5)
Percent change		-2.3	+2.3		-1.7	+1.7

Data are presented as number or number (%).

*The percent is the proportion of procedures performed each year relative to the total colonoscopy volume.

Table 3. National Colonoscopy Burden According to Age Group over the 12-Year Period in Korea

Year	Young age (<50 yr)			Screening age (50–74 yr)			Elderly age (≥75 yr)		
	Total volume	CS without polypectomy	Polypectomy	Total volume	CS without polypectomy*	Polypectomy*	Total volume	CS without polypectomy*	Polypectomy*
2002	131,431	124,226 (94.5)	7,205 (5.5)	125,060	109,097 (87.2)	15,963 (12.8)	7,854	6,844 (87.1)	1,010 (12.9)
2003	229,271	217,796 (95.0)	11,475 (5.0)	206,768	180,233 (87.2)	26,535 (12.8)	12,012	10,368 (86.3)	1,644 (13.7)
2004	267,815	251,194 (93.8)	16,621 (6.2)	262,325	222,634 (84.9)	39,691 (15.1)	16,050	13,638 (85.0)	2,412 (15.0)
2005	361,729	335,013 (92.6)	26,716 (7.4)	367,829	304,638 (82.8)	63,191 (17.2)	21,977	18,139 (82.5)	3,838 (17.5)
2006	442,551	401,190 (90.7)	41,361 (9.3)	483,284	386,253 (79.9)	97,031 (20.1)	31,699	25,416 (80.2)	6,283 (19.8)
2007	479,373	425,120 (88.7)	54,253 (11.3)	563,229	437,513 (77.7)	125,716 (22.3)	37,757	29,518 (78.2)	8,239 (21.8)
2008	508,168	439,933 (86.6)	68,235 (13.4)	654,693	494,628 (75.6)	160,065 (24.4)	44,752	34,100 (76.2)	10,652 (23.8)
2009	578,202	494,490 (85.5)	83,712 (14.5)	807,666	600,228 (74.3)	207,438 (25.7)	55,696	41,504 (74.5)	14,192 (25.5)
2010	588,331	493,360 (83.9)	94,971 (16.1)	946,442	684,963 (72.4)	261,479 (27.6)	66,915	48,053 (71.8)	18,862 (28.2)
2011	709,141	577,893 (81.5)	131,248 (18.5)	1,186,855	834,456 (70.3)	352,399 (29.7)	79,283	54,975 (69.3)	24,308 (30.7)
2012	691,351	552,549 (79.9)	138,802 (20.1)	1,351,311	926,350 (68.6)	424,961 (31.4)	95,488	63,416 (66.4)	32,072 (33.6)
2013	649,927	507,664 (78.1)	142,263 (21.9)	1,340,951	896,796 (66.9)	444,155 (33.1)	107,972	69,604 (64.5)	38,368 (35.5)
Percent change		-1.6	+1.6		-2.0	+2.0		-2.1	+2.1

Data are presented as number or number (%).

*The percent is the proportion of procedures performed each year relative to the total colonoscopy (CS) volume.

RESULTS

1. National burden of colonoscopy

Table 1 shows the longitudinal time change in the national colonoscopy burden for 12 years, based on 14,511,158 colonoscopies on 13,219,781 patients. Compared with the total volume of colonoscopy in 2002, the total volume of colonoscopy doubled within 2 years in 2004, quadrupled within 5 years in 2007, hextupled within 8 years in 2010, and octupled within 10 years in 2012. The annual proportion of polypectomy performed at each year among the total volume of colonoscopy significantly increased by +2.0% from 2002 to 2013 (p<0.001). However, in-patient polypectomy rate per year significantly decreased by

-2.4% (p<0.001).

2. National burden of colonoscopy according to sex and age group

The overall colonoscopy burden was higher in men than women with ratio of 1.2 to 1 (Table 2). Compared with the volume of polypectomy in 2002, the proportion of polypectomy among the total volume of colonoscopy per year was significantly increased for both sexes in 12 years (both p<0.001). For sex difference, the proportion of polypectomy performed at each year among the total volume of colonoscopy was significantly increased in men than in women (2.3% vs 1.7%, p<0.001).

The burden of total colonoscopy in young age, screening age,

Table 4. National Colonoscopy Burden According to Healthcare Facility Type over the 12-Year Period in Korea

Year	Primary healthcare facility				Secondary healthcare facility			
	Total facility	Total CS volume	CS without polypectomy*	Polypectomy	Total facility	Total CS volume	CS without polypectomy*	Polypectomy
2002	741	97,302	89,447 (91.9)	7,855 (8.1)	213	89,074	80,322 (90.2)	8,752 (9.8)
2003	941	173,580	161,535 (93.1)	12,045 (6.9)	307	172,338	155,935 (90.5)	16,403 (9.5)
2004	1,118	208,541	188,736 (90.5)	19,805 (9.5)	454	225,861	200,916 (89.0)	24,945 (11.0)
2005	1,281	286,832	252,915 (88.2)	33,917 (11.8)	571	328,030	286,629 (87.4)	41,401 (12.6)
2006	1,508	367,715	312,673 (85.0)	55,042 (15.0)	660	425,631	361,774 (85.0)	63,857 (15.0)
2007	1,635	420,900	346,348 (82.3)	74,552 (17.7)	717	481,575	397,277 (82.5)	84,298 (17.5)
2008	1,791	479,126	380,046 (79.3)	99,080 (20.7)	809	538,892	433,290 (80.4)	105,602 (19.6)
2009	1,894	584,781	452,727 (77.4)	132,054 (22.6)	856	627,587	499,776 (79.6)	127,811 (20.4)
2010	2,040	664,000	497,557 (74.9)	166,443 (25.1)	908	696,670	539,123 (77.4)	157,547 (22.6)
2011	2,221	862,130	627,247 (72.8)	234,883 (27.2)	950	857,009	642,009 (74.9)	215,000 (25.1)
2012	2,316	938,075	661,358 (70.5)	276,717 (29.5)	992	923,782	671,683 (72.7)	252,099 (27.3)
2013	2,408	918,035	626,622 (68.3)	291,413 (31.7)	1,020	916,029	648,732 (70.8)	267,297 (29.2)
Percent change			-2.4	+2.4			-1.9	+1.9

Year	Tertiary healthcare facility				Other healthcare facility			
	Total facility	Total CS volume	CS without polypectomy*	Polypectomy	Total facility	Total CS volume	CS without polypectomy*	Polypectomy
2002	41	77,969	70,398 (90.3)	7,571 (9.7)	0	0	0 (0.0)	0 (0.0)
2003	42	102,126	90,921 (89.0)	11,205 (11.0)	1	7	6 (85.7)	1 (14.3)
2004	43	111,648	97,691 (87.5)	13,957 (12.5)	5	140	123 (87.9)	17 (12.1)
2005	41	136,467	118,046 (86.5)	18,421 (13.5)	14	206	200 (97.1)	6 (2.9)
2006	43	163,608	137,889 (84.3)	25,719 (15.7)	18	580	523 (90.2)	57 (9.8)
2007	45	176,816	147,695 (83.5)	29,121 (16.5)	28	1,068	831 (77.8)	237 (22.2)
2008	48	188,401	154,408 (82.0)	33,993 (18.0)	53	1,194	917 (76.8)	277 (23.2)
2009	44	227,388	182,176 (80.1)	45,212 (19.9)	69	1,808	1,543 (85.3)	265 (14.7)
2010	44	238,498	187,558 (78.6)	50,940 (21.4)	84	2,520	2,138 (84.8)	382 (15.2)
2011	45	252,192	194,992 (77.3)	57,200 (22.7)	97	3,948	3,076 (77.9)	872 (22.1)
2012	47	269,869	204,870 (75.9)	64,999 (24.1)	127	6,424	4,404 (68.6)	2,020 (31.4)
2013	45	259,116	194,901 (75.2)	64,215 (24.8)	136	5,670	3,809 (67.2)	1,861 (32.8)
Percent change			-1.4	+1.4				

Data are presented as number or number (%).

*The percent is the proportion of procedures performed each year relative to the total colonoscopy (CS) volume.

and elderly age groups was 38.8%, 57.2%, and 4.0%, respectively (Table 3). Compared with the volume of polypectomy in 2002, the proportion of polypectomy among the total volume of colonoscopy per year was significantly increased for all age groups in 12 years (all $p < 0.001$). For age group difference, the proportion of polypectomy among the total volume of colonoscopy per year significantly increased in the screening and elderly age groups compared with the young age group (2.0% and 2.1% vs 1.6%, both $p < 0.001$).

3. National burden of colonoscopy according to healthcare facility type

Our analysis was focused on primary, secondary, and tertiary facilities, as the colonoscopy volume in other facility type was only 0.2% (Table 4). The number of facilities claimed that colonoscopy procedures increased by 3.2-fold and 4.8-fold in primary and secondary facilities in 12 years. In total, 41.3%, 43.3%, and 15.2% of polypectomies were performed in primary, secondary, and tertiary facilities for 12 years. Compared with the colonoscopy database in 2002, the proportion of polypectomy among the total volume of colonoscopy per year significantly increased in primary, secondary, and tertiary facilities by 2.4%, 1.9%, and 1.4%, respectively (all $p < 0.001$). The annual polypectomy rate of each facility type among total polypectomies was significantly increased only in the primary facilities ($p < 0.001$), but, significantly decreased in the tertiary facilities ($p < 0.001$) and not changed in the secondary facilities ($p = 0.274$) (Fig. 1).

4. Colonoscopy burden by high-volume facility

Compared to that in the 2002 database, the number of high-volume facility significantly increased by 2.8% and by 2.0% in primary and secondary facilities (both $p < 0.001$), but was not changed in the tertiary facilities ($p > 0.1$) (Table 5). The annual colonoscopy volume covered by a high-volume facility among the total volume of colonoscopy significantly increased in primary and secondary facilities by 1.8% and by 0.4% per year (both $p < 0.001$), but it was not changed in the tertiary facilities in 12 years ($p = 0.196$).

5. Early repeat colonoscopy within 12 months

Overall, 8.4% of 13,219,781 persons had an early repeat colonoscopy, and 3.3% of 10,922,565 persons had an early repeat colonoscopy without polypectomy by per-patient analysis (Supplementary Table 1). The proportion of an early repeat colonoscopy without polypectomy among the total volume of colonoscopy significantly decreased in 12 years (by 0.3% for two colonoscopies and by 0.1% for ≥ 3 colonoscopies) (both $p < 0.001$).

DISCUSSION

This population-based study is the first Asian study that investigated the national colonoscopy volume according to age, sex, and healthcare facility type. The national colonoscopy volume has progressively increased in all sex, age groups, and healthcare facility types in the 12 years. The volume of colonoscopic polypectomy significantly increased in men than in women and in the screening age group than in the young age group. These findings are predictable because old age and male sex are well-known risk factors for colorectal neoplasia.^{18,19} The colonoscopic polypectomy volume significantly increased in the primary facility than the secondary and tertiary facility. A steep rise in the volume of colonoscopy by the primary healthcare facilities may be explained by the introduction of the "National CRC Screening Program" in 2004 in Korea.⁸ In Canada, similarly, the proportion of colonoscopies performed in the nonhospital setting increased with the introduction of the "ColonCancerCheck" program: 18.9% increase from 2000 to 2007²⁰ and 35.1% increase from 2013 to 2014.²¹ Higher rates of the polypectomy in the primary healthcare facilities may be explained by that diminutive polyps may be removed by polypectomy, not by biopsy forceps, as well as that non-adenomatous polyps on the distal colon may be removed by polypectomy in primary healthcare facilities. Our findings may indicate that healthcare resources should be prioritized such that there is adequate colonoscopic capacity, especially for men, screening age group, and primary healthcare facilities.

We could estimate the capacity of screening colonoscopy at the population level on the basis of our data. In 2012, 15,537,702 Koreans were invited to undergo CRC screening and 3,884,839 (25.0%) of them underwent CRC screening

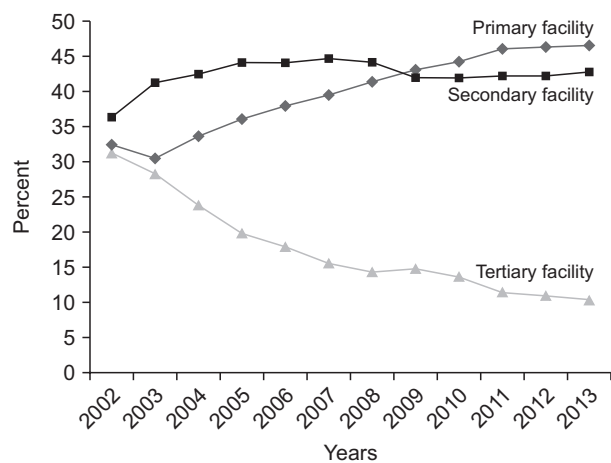


Fig. 1. Annual colonoscopic polypectomy volume in each type of healthcare facility. The proportion of colonoscopic polypectomies performed relative to the total polypectomy volume significantly increased by 1.6% in primary facilities and decreased by 1.8% in tertiary facilities (both $p < 0.001$) compared with the rates in the 2002 database.

Table 5. Colonoscopy Burden of HVFs over the 12-Year Period in Korea

Year	Primary facility				Secondary facility				Tertiary facility			
	Total facility	HVF	Total CS volume	CS by HVF	Total facility	HVF	Total CS volume	CS by HVF	Total facility	HVF	Total CS volume	CS by HVF
2002	741	138 (18.6)	97,302	65,532 (67.3)	213	78 (36.6)	89,074	81,441 (91.4)	41	38 (92.7)	77,969	77,607 (99.5)
2003	941	241 (25.6)	173,580	128,733 (74.2)	307	146 (47.6)	172,338	162,967 (94.6)	42	42 (100.0)	102,126	102,126 (100.0)
2004	1,118	310 (27.7)	208,541	159,744 (76.6)	454	195 (43.0)	225,861	209,954 (93.0)	43	42 (97.7)	111,648	111,646 (100.0)
2005	1,281	405 (31.6)	286,832	230,342 (80.3)	571	273 (47.8)	328,030	309,221 (94.3)	41	41 (100.0)	136,467	136,467 (100.0)
2006	1,508	497 (33.0)	367,715	302,222 (82.2)	660	363 (55.0)	425,631	407,472 (95.7)	43	42 (97.7)	163,608	163,599 (100.0)
2007	1,635	555 (33.9)	420,900	349,481 (83.0)	717	371 (51.7)	481,575	457,269 (95.0)	45	42 (93.3)	176,816	176,812 (100.0)
2008	1,791	623 (34.8)	479,126	400,216 (83.5)	809	418 (51.7)	538,892	511,956 (95.0)	48	43 (89.6)	188,401	188,372 (100.0)
2009	1,894	737 (38.9)	584,781	505,555 (86.5)	856	489 (57.1)	627,587	602,607 (96.0)	44	43 (97.7)	227,388	227,319 (100.0)
2010	2,040	824 (40.4)	664,000	578,234 (87.1)	908	518 (57.0)	696,670	668,812 (96.0)	44	43 (97.7)	238,498	238,482 (100.0)
2011	2,221	1,030 (46.4)	862,130	771,774 (89.5)	950	588 (61.9)	857,009	830,944 (97.0)	45	43 (95.6)	252,192	252,177 (100.0)
2012	2,316	1,113 (48.1)	938,075	847,351 (90.3)	992	613 (61.8)	923,782	896,816 (97.1)	47	46 (97.9)	269,869	269,704 (99.9)
2013	2,408	1,113 (46.2)	918,035	820,108 (89.3)	1,020	613 (60.1)	916,029	887,043 (96.8)	45	44 (97.8)	259,116	259,115 (100.0)
Percent change		+2.8		+1.7		+2.0		+0.3		+0.0		+0.0

Data are presented as number or number (%). A high volume facility (HVF) was defined as a facility with an annual colonoscopy (CS) volume of more than 200 colonoscopies.

with the “National CRC Screening Program.”⁸ One-third of the colonoscopic capacity may be used for CRC screening, because screening indication was about one-third of the total colonoscopy.²² Theoretically, if the 3,884,839 persons are eligible for CRC screening and one-third (i.e., 699,617) of the total volume of colonoscopy of 2012 are provided, 5.6 years may be required to screen the potential population of CRC screening in 2012. Therefore, 5- to 10-year interval of screening colonoscopy may cover all eligible CRC screening population in Korea. However, the potential capacity of screening colonoscopy at the population level may consider the growing rate of the target population, participation rate of screening program, screening interval, cost-effectiveness, and safety and quality of colonoscopy screening.

In previous studies, the quality of colonoscopy was suboptimal in primary healthcare facilities.^{20,21,23-25} In a population-based study from Ontario,²⁰ the odds ratio of early repeat colonoscopy ≤ 5 years after a negative complete colonoscopy was 1.26 when the index colonoscopy had been performed in a non-hospital setting. Similarly, the adjusted odds ratio for an early repeat colonoscopy ≤ 6 months was 1.41 when baseline colonoscopy was performed at a nonhospital facility compared with a teaching or community hospital.²¹ The early repeat colonoscopy at a nonhospital facility may be explained by their suboptimal baseline colonoscopy. In addition, direct access colonoscopy of primary facility had lower detection rate of large (≥ 10 mm) polyp and lower completion rate of colonoscopy than conventional colonoscopy group.²³ An important variation in colonoscopy quality among outpatient facilities was suggested by significant variation in the unplanned hospital visits within 7 days of colonoscopy.²⁴ In a retrospective study from Florida,²⁵ a higher risk of adverse events was associated with colonoscopies performed in ambulatory surgery centers (odds ratio, 1.27; 95% confidence interval, 1.16 to 1.40). Considering the predominantly increasing colonoscopy volume in primary healthcare facilities, the colonoscopy quality improvement program may be reinforced in primary healthcare facilities.

We also investigated the volume of an early repeat colonoscopy within 12 months. The volume of an early repeat colonoscopy without polypectomy among the total volume of colonoscopy decreased by 0.3% for two colonoscopies and by 0.1% for ≥ 3 colonoscopies from 2002 to 2013. In Canada, 2.4% of 334,663 persons had an early repeat colonoscopy within 6 months.²¹ In the Veterans Health Administration data,²⁶ colonoscopy was used more frequently than the recommended intervals on guidelines by 16% of patients without adenoma. In addition, 46.2% of the Medicare population underwent a repeat examination within 7 years and 23.5% of patients had no clear indication for the early repeat examination.²⁷ In our study, the number of high-volume facility significantly increased in primary and secondary facilities, and the annual colonoscopy volume covered by the high-volume facilities also increased

regardless of facility types. For example, only 11.7% of colonoscopy volume in primary facilities and 3.2% of colonoscopy volume in secondary facilities was performed in low-volume facilities in 2013. Therefore, the cost-effective strategy to increase colonoscopy quality may be focused on high-volume facilities in Korea.

The use of a NHIS enabled us to perform the largest study to date that assessed the national volume of colonoscopy, and the results are virtually free from referral bias and readily generalizable owing to the population-based design. However, some limitations should be considered. We concede that one of the limitations of our study is secondary data with the uncertainty regarding the accuracy of the diagnosis. However, previous studies with NHIS as data sources have generally shown that procedures and diagnoses are coded accurately.^{14,15} As no specific details of the colonoscopy were recorded in the NHIS, safety, quality, and the cost of colonoscopy were not addressed in this study. In addition, we cannot assess detailed clinical information for the cause of an early repeat colonoscopy within 12 months. We defined high-volume facility (i.e., annual colonoscopy volume ≥ 200) based on some evidence,^{16,17} but it may still be arbitrary as it was a criterion for an endoscopist, not a healthcare facility. In a German screening colonoscopy registry, the detection rate of any neoplasm was better for annual colonoscopy volume ≥ 200 than annual colonoscopy volume < 50 (27.5% vs 21.9%, $p < 0.001$).¹⁶ Spanish Society of Gastrointestinal Endoscopy also recommended at least 200 annual screening colonoscopies to maintain colonoscopy quality in CRC screening.¹⁷

In conclusion, the national volume of colonoscopy has been progressively increasing regardless of sex, age group, and healthcare facility types for the past 12 years in Korea. Healthcare resources should be prioritized such that there is adequate colonoscopic capacity, especially for men, subjects of screening age, and primary healthcare facilities. Considering difference in colonoscopy quality among facilities and majority of colonoscopy volume covered by high-volume facility, cost-effective strategy to improve colonoscopy quality may be focused on primary healthcare facilities and high-volume facilities in Korea.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTIONS

Study concept and design, analysis, and interpretation of data, drafting of the manuscript, critical revision of the manuscript for important intellectual content: J.M.C., H.S.K. Data management, statistical analysis: M.S.K., G.U.P., S.P., J.K.L., S.Y.K., S.J.K., H.H.L. Acquisition of data, administrative, and technical support of this study: J.S.K., W.H.K. Study supervision: J.M.C., H.S.K., J.S.K., W.H.K.

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