Utilization and quality assessment of digestive endoscopy in China: results from 5-year consecutive nationwide surveys

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Abstract

Background: Worldwide, the volume and availability of digestive endoscopy have undergone dramatic development in recent years, with increasing attention on quality assurance. We investigated the utilization and quality of digestive endoscopy in China from 2015 to 2019 and developed a quantitative quality evaluation tool for medical institutions.

Methods: We invited all tertiary/secondary hospitals in Chinese mainland to participate in the survey annually. The questionnaires included the personnel, annual volume, and quality indicators of endoscopy. An endoscopy quality index (EQI) was developed based on recorded quality indicators using principal component analysis to determine the relative weight.

Results: From 2015 to 2019, 806, 1412, 2644, 2468, and 2541 hospitals were respectively enrolled in this study. The average annual volume of endoscopy increased from 12,445 to 16,206 (1.30-fold) and from 2938 to 4255 (1.45-fold) in tertiary and secondary hospitals, respectively. The most obvious growth was observed in diagnostic colonoscopy (1.44-fold for all hospitals after standardization). The proportion of early cancer among all esophageal and gastric cancers during diagnostic esophagogastroduodenoscopy increased from 12.3% (55,210/448,861) to 17.7% (85,429/482,647) and from 11.4% (69,411/608,866) to 16.9% (107,192/634,235), respectively. The adenoma detection rate of diagnostic colonoscopy increased from 14.9% (2,118,123/14,215,592) to 19.3% (3,943,203/20,431,104). The EQI model included 12 quality indicators, incorporating 64.9% (7.792/12) of the total variance into one comprehensive index. According to the EQI measurements, the quality of endoscopy was higher in tertiary hospitals and hospitals in developed areas with higher volume or more endoscopists than that in other hospitals.

Conclusions: Digestive endoscopy in China has developed considerably in recent years in terms of both volume and quality. The EQI is a promising tool to quantify the quality of endoscopy at different hospitals.

Keywords: Endoscopy, gastrointestinal; Health care surveys; Principal component analysis; Quality control

Introduction

Digestive endoscopy plays an essential role in the diagnosis and treatment of various digestive diseases. In the era of value- and quality-based healthcare, increasing attention has been directed to the quality of endoscopy. Recent studies have shown that the quality of techniques, such as esophagogastroduodenoscopy (EGD) and colonoscopy, has increased through quality improvement programs,[1-4] and developing a framework to measure components of quality is most effective.[5-7] Guidelines on quality control of endoscopy have been developed by many countries, and performance measures have been developed for specific techniques.[8-12] However, to our knowledge, a concise, comprehensive, and quantitative quality assessment index for endoscopy services for medical institutions has not been applied yet.

During the last decade, there has been a dramatic development in digestive endoscopy in China, the largest developing country worldwide.[13-16] In 2015, the National Digestive Endoscopy Improvement System (NDEIS)

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of China was established, and an initial set of quality indicators was proposed according to international practice guidelines and domestic conditions. The NDEIS then began a national annual survey on endoscopy services, aiming to investigate utilization, survey quality, and acquire baseline information for quality indicators of digestive endoscopy in Chinese mainland.

In this study, we report the utilization and quality of digestive endoscopy in Chinese mainland based on the results of five consecutive national surveys, which were conducted between 2015 and 2019. Moreover, we developed a quantitative quality evaluation tool, the endoscopy quality index (EQI), based on the collected data for digestive endoscopy services of medical institutions, which may also provide a reference for other countries.

Methods

Conduct of the survey

The surveys (from Survey 2015 to Survey 2019) were initiated by the NDEIS and were supervised by the National Health Commission of the People's Republic of China. We invited all tertiary/secondary hospitals in Chinese mainland through local health authorities, covering all 31 provinces, autonomous regions, and municipalities. In Chinese mainland, hospitals are classified into tertiary, secondary, and primary, from the highest to lowest levels. Tertiary hospitals provide high-level specialist health services to several regions, and secondary hospitals provide general and special health services to several communities. In essence, tertiary and secondary hospitals of China play the role of the tertiary and secondary referral centers operating in Western countries, and digestive endoscopy is mainly performed in these hospitals. Participating hospitals were designated as personnel to complete the questionnaires. The predesigned structured questionnaires were annually published online at http://www.ncis.cn/, and the definitions and explanations of each indicator were attached. All information were collected at the medical-institution level, and endoscopist-level and individual-patient-level information were not included. This study was exempted from ethical review by the institutional review board of Shanghai Changhai Hospital.

Contents of the questionnaire

The questionnaires included three aspects: (1) basic information and personnel of endoscopy centers, such as the hospital location, grade, and number of endoscopists; (2) utilization of digestive endoscopy, including performance of certain techniques (such as diagnostic EGD, diagnostic colonoscopy, endoscopic retrograde cholangiopancreatography [ERCP], endoscopic ultrasound [EUS], endoscopic submucosal dissection [ESD], and capsule endoscopy [CE]) and the annual volume. Diagnostic EGD and colonoscopy were loosely defined and included those with screening, surveillance, and diagnostic indications; and (3) data for quality indicators of digestive endoscopy.

In 2015, 15 key quality indicators of digestive endoscopy were proposed by the expert panel (consisting of 27 experts in digestive endoscopy or quality management) of the NDEIS after two rounds of Delphi method deliberations [Supplementary Table 1, http://links.lww.com/CM9/B306]. Several indicators were not included in the surveys because of the difficulty in obtaining accurate data [Supplementary Table 2, http://links.lww.com/CM9/B306]. The definitions and calculation method of the quality indicators were mostly consistent with the international guidelines.[4-8] Owing to the high incidence of esophageal and gastric cancers in China, early diagnosis with EGD is the focus of quality control. Therefore, the proportion of early cancer among all esophageal and gastric cancers has been proposed as an outcome indicator for diagnostic EGD. Esophageal and gastric tumors were diagnosed using biopsy specimens according to the Vienna classification for gastrointestinal epithelial neoplasia.[17] Severe adverse events included were bleeding, acute pancreatitis, sepsis, perforation, and other conditions requiring surgical intervention, disability, and death attributable to endoscopic procedures.

Data inspection and analysis

Computer logical tests and manual inspections were conducted to assess the quality of the original data. The origin of the data and selection criteria are shown in Figure 1. Since the sampling of the current surveys was non-random, we retrieved basic information of all hospitals that performed digestive endoscopy in 2019 from the National Health Commission of China and investigated the representativeness of our data by comparing the location and grade of hospitals in Survey 2019 with the official information. The results for all included hospitals were standardized according to the constituent ratios of tertiary and secondary hospitals in the official information. The definition of the four economic regions of (Northeast, East, Central, and West) and data on socioeconomic indicators for each province were acquired from the National Bureau of Statistics of China (http://www.stats.gov.cn).

Development of the EQI

The data of 12 quality indicators from Survey 2019 were used to develop the EQI [Supplementary Table 2, http://links.lww.com/CM9/B306 and Eq. (1)]. We standardized each indicator to eliminate the influence of dimensions and negative indicators (Eqs (2) and (3)). Principal component analysis (PCA) was used to determine the weights of various indicators. PCA is an objective weighting method that has been widely used in the quantitative analysis of quality evaluation of food and drugs in addition to the development of medical scales.[18-21] Principal components with eigenvalues >1 were extracted and included in the analysis. The component score coefficients were derived from the eigenvectors of the extracted principal components. The weight of each quality indicator was determined by the average of the corresponding component score coefficients weighted by the eigenvalues of the principal components (Eq. (4)) after normalization (Eq. (5)).

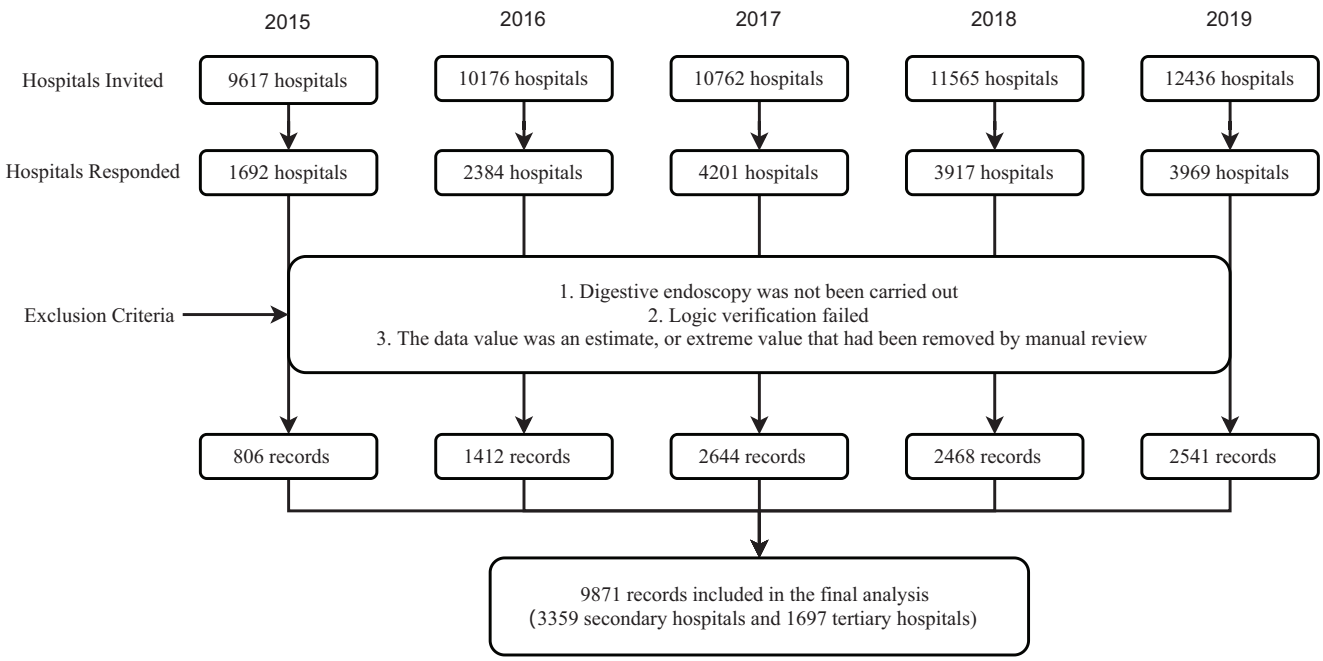

Figure 1: The flow diagram of the survey and data inspection. The survey refers to the national annual surveys on endoscopy services (from 2015 to 2019). A hospital participated in one annual survey would generate one record. Some hospitals participated in multiple surveys, and had more than one record.

$$EQI = \sum_{i=1}^{n} k_i' x_i' \times 1000 \, (n = 12) \quad (1)$$

$$x_i' = \frac{(x_{\max} - x_i)}{(x_{\max} - x_{min})} \quad (2)$$

$$x_i' = \frac{(x_i - x_{min})}{(x_{\max} - x_{min})} \quad (3)$$

$$k_i = \frac{\sum_{j=1}^{p} \lambda_j e_{ij}}{\sum_{j=1}^{p} \lambda_j} (p = number\ of\ included\ components) \quad (4)$$

$$k_i' = \frac{k_i}{\sum_{i=1}^{n} k_i} (n = 12) \quad (5)$$

where x_i is the actual value of indicator i in a certain hospital, x_i' represents the standardized value of x_i, and k_i is the weight of indicator i. $x_{\max}$ represents the maximum actual value of the indicator, $x_{\min}$ represents the minimum actual value of the indicator, and k_i refers to the weight of indicator i before normalization. λ_j is the eigenvalue of component j, and e_{ij} is the component score coefficient of component j.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation, and categorical data are expressed as the number of each category and frequency. The Kaiser-Meyer-Olkin (KMO) and Bartlett tests of sphericity were used to determine the applicability of PCA. To identify potential factors associated with the EQI, univariate linear analyses were performed, and factors with a P value < 0.05 were included in the multivariate linear regression to identify independent predictors. If multiple collinearity existed, the variable with highest variance inflation factor were excluded from the model one by one, until no significant collinearity was detected. To determine the best format for the factors, we performed an Akaike information criterion analysis. Statistical analyses were performed using SPSS version 26.0 for Windows (IBM Corp., Armonk, NY, USA). A two-sided P value < 0.05 was considered statistically significant.

Results

From 2015 to 2019, 1692, 2384, 4201, 3917, and 3969 hospitals responded to the survey, respectively. After data checking and logic verification, 806, 1412, 2644, 2468, and 2541 hospitals were included in the analysis [Figure 1]. In 2019, a total of 6253 tertiary and secondary hospitals performed digestive endoscopy in Chinese mainland, indicating that 40.6% of these were included in Survey 2019. The constituent ratios of provincial regions in Survey 2019 were significantly correlated with all 6253 hospitals ($r = 0.766$, $P < 0.001$; Supplementary Table 3, http://links.lww.com/CM9/B306), and the proportions of tertiary and secondary hospitals were not significantly different ($P = 0.358$; Supplementary Table 4, http://links.lww.com/CM9/B306), suggesting that the representativeness of the survey was acceptable.

Utilization of digestive endoscopy

The number of endoscopists and annual volume of endoscopy per hospital are shown in Table 1. From 2015 to 2019, the number of endoscopists per hospital

Table 1: The volume and quality performance of digestive endoscopy in Chinese mainland from 2015 to 2019.

Items	Tertiary hospitals					Secondary hospitals					All included hospitals (standardized)*				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Endoscopists number per hospital	10.1	9.9	10.4	11.2	10.2	3.3	2.9	3.1	3.6	3.3	4.8	4.4	4.7	5.3	4.8
Annual volume per hospital															
All digestive endoscopy	12,445	14,460	14,888	16,300	16,206	2938	2965	2906	3862	4255	5039.5	5506.0	5554.6	5866.8	6896.8
Diagnostic EGD	8775	8879	9141	9639	9715	2516	2514	2474	2533	2410	3899.6	3921.0	3714.1	4057.8	4024.8
Diagnostic colonoscopy	2983	3184	3573	4180	4451	621	619	618	804	846	1143.1	1186.0	1271.2	1405.4	1642.9
Small-bowel CE	40	45	49	57	54	26	21	16	21	19	29.1	26.3	65.4	25.1	26.7
ESD	81	82	83	98	97	20	20	23	20	21	33.5	33.7	36.3	39.6	37.8
ERCP	150	154	151	160	152	31	35	37	33	36	57.3	61.3	70.0	64.2	61.6
EUS	360	368	373	400	410	46	48	70	75	85	115.4	118.7	116.7	142.9	156.8
Quality indicators of enrolled hospitals (%)															
Severe adverse event rate	0.013	0.022	0.008	0.012	0.004	0.013	0.049	0.008	0.005	0.003	0.013	0.043	0.008	0.007	0.003
Proportion of early cancer in all esophageal cancer during diagnostic EGD	12.4	12.9	14.3	17.9	18.6	12.3	16.5	18.9	17.3	17.5	12.3	15.7	17.9	17.4	17.7
Proportion of early cancer in all gastric cancer during diagnostic EGD	11.9	11.9	14.3	16.7	18.2	11.3	16.3	16.4	16.1	16.5	11.4	15.3	15.9	16.2	16.9
Complete examination rate of diagnostic EGD	-	-	-	-	97.4	-	-	-	-	95.6	-	-	-	-	97.2
Rate of adequate bowel preparation before colonoscopy	-	-	-	-	86.0	-	-	-	-	85.7	-	-	-	-	85.8
Cecal intubation rate during colonoscopy	97.1	98.9	97.2	96.6	96.0	97.0	96.6	94.6	95.3	94.7	97.0	97.1	95.2	95.6	95.0
ADR of colonoscopy	16.6	17.0	16.7	17.4	18.6	14.4	15.5	15.0	14.6	19.5	14.9	15.8	15.4	15.2	19.3
Complete examination rate of small-bowel CE	96.3	96.2	-	-	93.6	99.1	96.0	-	-	95.2	98.5	96.0	-	-	94.8
Complete resection rate of ESD for gastrointestinal early cancer	94.5	94.4	95.3	95.7	96.5	93.2	93.1	94.1	94.3	94.4	93.5	93.4	94.4	94.6	94.9
Success rate of deep cannulation of the ducts of interest during ERCP	89.4	87.4	93.0	94.0	94.4	90.2	87.1	92.3	93.4	96.9	90.0	87.2	92.5	93.5	96.3
Success rate of extraction of common bile duct stones <1 cm	-	-	-	-	95.1	-	-	-	-	93.9	-	-	-	-	94.2
Complete examination rate of the desired lesions during diagnostic EUS	-	-	-	-	99.3	-	-	-	-	99.8	-	-	-	-	99.7
Diagnostic rate for malignancy in patients undergoing EUS-FNA of suspected malignant masses	87.3	88.3	91.1	89.2	88.4	-	-	-	-	-	-	-	-	-	-

*The data of all hospitals were standardized according to the actual number of secondary and tertiary hospitals in Chinese mainland in 2019. -: indicators were not collected, data are unavailable. ADR: Adenoma detection rate; CE: Capsule endoscopy; EGD: Esophagogastroduodenoscopy; ERCP: Endoscopic retrograde cholangiopancreatography; ESD: Endoscopic submucosal dissection; EUS: Endoscopic ultrasound; FNA: Fine-needle aspiration.

was stable (5-year average: 10.4 in tertiary hospitals, 3.2 in secondary hospitals), while the average annual volume of endoscopy per hospital increased from 12,445 to 16,206 (1.30-fold) in tertiary hospitals and from 2938 to 4255 (1.45-fold) in secondary hospitals. The most obvious growth was observed for diagnostic colonoscopy (from 2983 to 4451, 1.49-fold) and small-bowel CE (from 40 to 54, 1.35-fold) in tertiary hospitals and for diagnostic colonoscopy (from 621 to 846, 1.36-fold) and EUS (from 46 to 85, 1.85-fold) in secondary hospitals. The volume of diagnostic colonoscopy increased by 1.44-fold (from 1143.1 to 1642.9) for all hospitals after standardization. In 2019, almost all hospitals performed diagnostic EGD (tertiary hospitals: 99.2% (2728/2749), secondary hospitals: 99.2% (9610/9687)), while 98.2% (2700/2749) of tertiary hospitals and 87.2% (8447/9687) of secondary hospitals performed diagnostic colonoscopies. ESD, ERCP, and EUS were performed in 68.3% (1877/2749), 70.9% (1949/2749), and 49.8% (1369/2749) of tertiary hospitals and 18.4% (1782/9687), 11.5% (1114/9687), and 5.7% (552/9687) of secondary hospitals, respectively. The ratio of endoscopists to digestive endoscopy volume in 2019 was 1:1589 in tertiary hospitals and 1:1289 in secondary hospitals.

Quality of digestive endoscopy

The overall quality of digestive endoscopy improved from 2015 to 2019 [Table 1]. The rate of severe adverse events decreased from 0.013% to 0.003%. The proportion of early cancer among all esophageal cancers during diagnostic EGD increased from 12.4% to 18.6% in tertiary hospitals and from 12.3% to 17.5% in secondary hospitals. The proportion of early gastric cancers increased from 11.9% to 18.2% in tertiary hospitals and from 11.3% to 16.5% in secondary hospitals. The adenoma detection rate (ADR) of colonoscopy increased from 16.6% to 18.6% in tertiary hospitals and from 14.4% to 19.5% in secondary hospitals.

Construction of the EQI

In total, 12 quality indicators were included in the PCA after data standardization to construct the EQI. The results of the KMO and Bartlett tests of sphericity were 0.734 and $P < 0.001$, respectively, suggesting that PCA was suitable for the current data. The first four principal components with eigenvalues >1, accounting for 64.9% of the total variance, were extracted and utilized to construct the EQI [Supplementary Table 5, http://links.lww.com/CM9/B306]. The weights of the 12 quality indicators used for calculating the EQI are listed in Table 2. The proportion of early cancer in all esophageal cancer during diagnostic EGD, proportion of early cancer in all gastric cancer during diagnostic EGD, adequate bowel preparation rate before colonoscopy, and cecal intubation rate during colonoscopy had the highest weights (≥0.1), in calculating the EQI. An online EQI calculator is available on the website of the NDEIS (https://www.ndeis.cn/home/ceq).

Table 2: Component matrix and weights of quality control indicators to calculate EQI for digestive endoscopy.

Indicators	Component				Weights
	1	2	3	4	
The proportion of early cancer in all esophageal cancer during diagnostic EGD	0.125	0.356	0.805	−0.052	0.12
The proportion of early cancer in all gastric cancer during diagnostic EGD	0.153	0.358	0.798	−0.054	0.12
Rate of adequate bowel preparation before colonoscopy	0.450	0.662	−0.274	0.024	0.10
Cecal intubation rate during colonoscopy	0.558	0.574	−0.335	0.027	0.10
Complete resection rate of ESD for early cancer	0.774	−0.153	0.041	0.031	0.09
Success rate of deep cannulation of the ducts of interest during ERCP	0.848	−0.340	0.025	0.000	0.08
Success rate of extraction of common bile duct stones <1 cm	0.836	−0.335	0.027	−0.016	0.08
ADR of colonoscopy	0.452	0.346	−0.113	0.034	0.08
Complete examination rate of small-bowel CE	0.640	−0.250	0.077	0.051	0.07
Diagnostic rate for malignancy in patients receiving EUS-FNA of suspected malignant masses	0.540	−0.238	0.147	0.028	0.06
Complete examination rate of diagnostic EGD	0.281	0.372	−0.232	−0.227	0.05
Severe adverse event rate	−0.022	0.101	0.044	0.970	0.03

ADR: Adenoma detection rate; CE: Capsule endoscopy; EGD: Esophagogastroduodenoscopy; EQI: Endoscopy quality index; ERCP: Endoscopic retrograde cholangiopancreatography; ESD: Endoscopic submucosal dissection; EUS: Endoscopic ultrasound; FNA: Fine-needle aspiration.

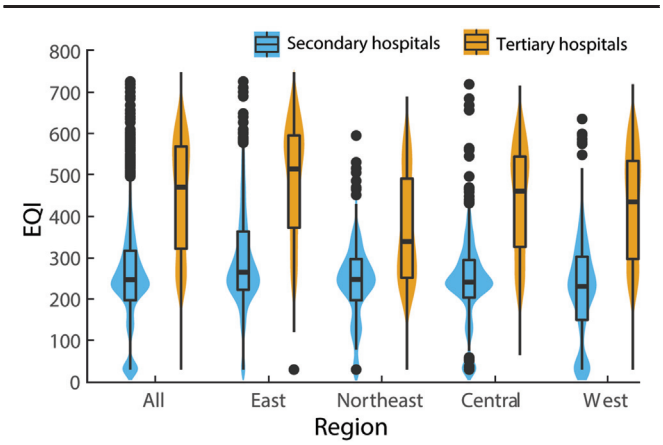

Figure 2: Distribution of the EQI to evaluate digestive endoscopy in different economic regions and grades of hospitals in 2019 (East China includes Beijing, Shanghai, Tianjin, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan. Northeast China includes Heilongjiang, Jilin, and Liaoning. Central China includes Anhui, Henan, Hubei, Hunan, Jiangxi, and Shanxi. West China includes Chongqing, Gansu, Guangxi, Guizhou, Yunnan, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Sichuan, Tibet, and Xinjiang). EQI: Endoscopy quality index.

The EQIs for hospitals participating in Survey 2019 were calculated. Significant variations in EQI were observed among hospitals in different regions and with different grades. Hospitals with high EQI were concentrated in large cities and developed areas. The distribution of the EQI with regard to different hospital grades and economic regions in 2019 is shown in Figure 2. For tertiary hospitals, the median EQI was 471.0 (interquartile range, 322.1–569.2), while the median EQI for secondary hospitals was 247.1 (interquartile range, 197.1–317.2). Both tertiary hospitals (median, 514.6; interquartile range, 370.9–596.4) and secondary hospitals (median, 265.0; interquartile range, 222.3–364.7) in eastern China had the highest EQI compared with hospitals in other regions.

Factors associated with the EQI

The results of the univariate analysis of factors associated with the EQI are shown in Supplementary Table 6, http://links.lww.com/CM9/B306. In the final multivariate model, hospital grade (β, 116.39; 95% confidence interval [CI], 105.10–127.68; $P < 0.01$; tertiary *vs.* secondary), number of endoscopists (β, 9.59; 95% CI, 8.70–10.48; $P < 0.01$), annual volume of endoscopy ($\times 10^3$) (β, 0.33; 95% CI, 0.14–0.52; $P < 0.01$), proportion of urban population (β, 1.85; 95% CI, 0.64–3.06; $P < 0.01$), and region where the hospital was located (Northeast [β, −41.67; 95% CI, −64.58 to −18.75; $P < 0.01$]; Central [β, −21.38; 95% CI, −36.54 to −6.22; $P < 0.01$]; West [β, −19.02; 95% CI, −35.00 to −3.04; $P = 0.02$]; all compared to East) were independently associated with the EQI, accounting for 47.3% of the total variance [Table 3]. The factors associated with the EQI were also investigated separately for secondary and tertiary hospitals, and 22.9% and 33.8% of the total variance were explained in the final multivariate model, respectively [Table 3].

Discussion

In this study, we presented the first comprehensive report of digestive endoscopy in China from 2015 to 2019, showing that utilization and quality had developed substantially during these 5 years. Moreover, we successfully built an EQI based on five process indicators and seven outcome indicators to quantify the quality of endoscopy of medical institutions in China. The geographical distribution and independent predictors of the EQI were further investigated.

China is a developing country and the present data demonstrate that digestive endoscopy in China is still at an early stage of development. First, the endoscopy volume is

Table 3: Independent predictors of the EQI assessed using multivariable linear regression analysis.

Variables	β (95% CI)	Standardized β	*P* values	Adjusted R^2
EQI of all hospitals				0.473
Grade of hospital (tertiary *vs.* secondary)	116.39 (105.10–127.68)	0.34	<0.01	
Number of endoscopists	9.59 (8.70–10.48)	0.38	<0.01	
Annual volume of endoscopy ($\times 10^3$)	0.33 (0.14–0.52)	0.05	<0.01	
Proportion of urban population	1.85 (0.64–3.06)	0.10	<0.01	
Region				
Northeast	−41.67 (−64.58 to −18.75)	−0.07	<0.01	
Central	−21.38 (−36.54 to −6.22)	−0.05	<0.01	
West	−19.02 (−35.00 to −3.04)	−0.05	0.02	
East	Reference			
Health expenditure ($\times 10^9$ CNY)	−0.12 (−0.29 to 0.04)	−0.03	0.13	
GDP per capita ($\times 10^3$ CNY)	0.01 (−0.36 to 0.39)	0.002	0.95	
EQI of secondary hospitals				0.229
Number of endoscopists	21.15 (18.79–23.51)	0.41	<0.01	
Annual volume of endoscopy ($\times 10^3$)	0.20 (0.02–0.39)	0.05	0.03	
Proportion of urban population (%)	2.03 (1.15–2.91)	0.13	<0.01	
Region				
Northeast	−14.47 (−39.64 to 10.71)	−0.03	0.26	
Central	−21.29 (−39.16 to −3.43)	−0.07	0.02	
West	−26.20 (−45.38 to −7.01)	−0.10	<0.01	
East	Reference			
EQI of tertiary hospitals				0.338
Number of endoscopists	4.91 (3.54–6.28)	0.29	<0.01	
Annual volume of endoscopy ($\times 10^3$)	2.60 (1.90–3.29)	0.30	<0.01	
Region				
Northeast	−77.00 (−113.32 to −40.67)	−0.16	<0.01	
Central	−33.00 (−59.23 to −6.75)	−0.09	0.01	
West	−25.12 (−51.43 to 1.20)	−0.08	0.06	
East	Reference			
Health expenditure ($\times 10^9$ CNY)	−0.09 (−0.34 to 0.17)	−0.02	0.51	
GDP per capita ($\times 10^3$ CNY)	0.01 (−0.37 to 0.37)	0.001	0.99	

CI: Confidence interval; CNY: Chinese Yuan; EQI: Endoscopy quality index; GDP: Gross domestic product.

increasing rapidly. From 2015 to 2019, the average annual endoscopy volume per hospital increased by 36.9%. This upward trend is steeper than corresponding trends in developed countries at approximately the same time. In the United States, the total endoscopy volume increased by 25.1% between 2013 and 2019.[5,22] In the United Kingdom, the total endoscopy volume increased by 12.5% between 2017 and 2019.[23,24] In Japan, the volume of EGD per hospital or clinic in 2017 was estimated to have increased by 6% or 11% compared with that in 2014, while that of colonoscopy increased by 8% or 13%.[25,26] Second, there remains a shortage of endoscopy resources. For basic endoscopy, >10% of secondary hospitals did not perform diagnostic colonoscopy in 2019. For advanced endoscopy, even in tertiary hospitals, ESD and ERCP could be performed in approximately 70% of the cases and EUS could be performed in only approximately half of the cases. In China, tertiary and secondary hospitals act as referral centers for cities and towns, respectively. We can speculate that many endoscopy techniques are not currently available in underdeveloped areas in China, and we suggest that greater financial support should be provided to those areas.

With the increasing volume of endoscopic procedures, the quality control of endoscopy has attracted worldwide attention. In this study, we observed a steady improvement in most of the quality indicators. The severe adverse event rate decreased from 0.013% to 0.003%, and the levels of indicators for advanced endoscopy (ERCP, ESD, and EUS) met the criteria set by the current guidelines in developed countries or by systematic reviews.[10,27,28] For colonoscopy, the ADR increased from 14.9% in 2015 to 19.3% in 2019 although it was much lower than that of screening colonoscopy in the United States (38.1%) and Germany (31.3% in men and 20.1% in women).[12,29] ADRs vary according to colorectal cancer incidence, procedure indication, and study design. In a multicenter study from the United Kingdom, the ADR for diagnostic colonoscopy (excluding screening colonoscopy) was 15.9%.[30] In the future, we will set performance measurements of colonoscopy for different indications and adjust them according to the local incidence of colorectal cancer in different areas.

China and other countries in eastern Asia have a high incidence of upper gastrointestinal cancer. Therefore, more emphasis was placed on diagnostic EGD. The ratio of diagnostic EGD to colonoscopy in China was 2.25 in 2019, similar to that in Japan (2.72, 2017),[25] but much higher than that in the United States (0.54, 2019)[22] and

the United Kingdom (1.23, 2019).[23] Since the indications for diagnostic EGD are similar among medical institutions in our country, the proportion of early cancer among all esophageal and stomach cancers mainly depends on the capability of and attention paid by the endoscopists. Therefore, we adopted two proportions as the outcome indicators for EGD. The present study showed that performance improved with time but was still <20% in 2019. This performance level is not optimal. In Japan and Korea, this proportion in the screening population was >50%.[31,32] To improve this situation, the NDEIS must initiate programs for upper gastrointestinal cancer screening, endoscopist training, and benchmarking of key indicators in the near future.

Defining an appropriate assessment tool is necessary to achieve continuous quality improvement. The global rating scale (GRS), a comprehensive quality assurance tool proposed by the Joint Advisory Group, has been used throughout the United Kingdom, Ireland, and beyond to underpin all aspects of high-quality endoscopy services, including clinical quality, patient experience, environment, and workforce.[33] The quality of endoscopy and patients' experiences in the United Kingdom have tremendously improved over nearly two decades of GRS application.[34] The American Society of Gastrointestinal Endoscopy and American College of Gastroenterology Task Force on Quality in Endoscopy systematically developed a series of clinical guidelines on quality indicators and initiated benchmarking among endoscopists, which also achieved positive effects.[2,4] However, implementation of such quality assurance programs requires either well-trained assessors or sophisticated information systems that capture data during daily practice, which are not available to a considerable number of medical institutions in China. In this study, we developed a concise and quantitative quality assessment tool for medical institutions based on 12 process/outcome indicators. We adopted the PCA method to determine the weights of each indicator, and >60% of the variance could be explained by this model. The application of the EQI allows the evaluation of a large number of medical institutions under the same criteria, more clearly demonstrates the strengths and weaknesses of the healthcare system, and guides all institutions toward better quality performance, defined based on the components and weights of the EQI. The process of constructing an EQI may provide reference for other countries in terms of quantitatively evaluating the quality of endoscopy or other medical procedures based on their different domestic conditions.

In the multivariate regression analysis, tertiary hospitals had higher EQIs than secondary hospitals, and hospitals located in the east of China tended to score higher than those in other regions, consistent with the socioeconomic development level. The number of endoscopists in each hospital was another important predictor of the EQI, highlighting the importance of sufficient human resources and proper workload for high-quality endoscopic procedures. Furthermore, the association between adequate volume and high practice quality has been proven in studies on colonoscopy[35] and ERCP,[36] and the annual volume of endoscopy was a significant predictor of the EQI in the current study.

This study has several limitations. First, the sampling of hospitals was non-random; therefore, selection bias could not be avoided. However, because of the large size, high regional coverage, and similarities with all hospitals performing digestive endoscopy in 2019, we considered the representativeness of the survey as acceptable. In fact, we are planning to implement a national endoscopy database that collects data from the hospital information system of each center, just as the United Kingdom, Japan, and the United States. Second, the EQI that we proposed requires further validation through health economics and outcome research. It is noteworthy that the EQI will be adjusted dynamically over time and in different countries. We will use the data collected in the present study to develop domestic performance measures and evaluate them in practice according to the Plan-Do-Study-Act cycle.[3]

In conclusion, the results presented in this study indicated that there has been considerable development in digestive endoscopy services in Chinese mainland in recent years. The EQI is a promising tool for quantifying the quality of endoscopy in different medical institutions.

Data sharing

The datasets generated and/or analyzed during the current study are not publicly available because of data protection regulations but are available from the corresponding author on reasonable request.

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Conflicts of interest

None.

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