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ORIGINAL SCIENTIFIC REPORT

Long-Term Trends and Predictors of Medical Resource Utilization and Medical Outcomes in Inguinal Hernia Repair: A Nationwide Cohort Study

Yi-Hung Kuo[1] · Chong-Chi Chiu[2,3] · Li-Ya Tseng[4] · Chien-Hung Wu[5] · Min Hui Chen[6] · Yu-Chao Fang[7] · Wei-Chi Tseng[8] · Chun-Hsiang Chen[7] · Shu-Chuan Jennifer Yeh[9,10] · Hon-Yi Shi[9,10,11,12]

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Abstract

Background Few studies have comprehensively and systematically analyzed nationwide samples. This study purposed to explore temporal trends and predictors of medical resource utilization and medical outcomes in these patients to obtain data that can be used to improve healthcare policies and to support clinical and administrative decision-making.

Methods This study used nationwide population data contained in the Longitudinal Health Insurance Database of Taiwan. The 14,970 inguinal hernia repair patients were enrolled in this study (age range, 18–100 years) from 1997 to 2013 in Taiwan. After temporal trends analysis of demographic characteristics, clinical characteristics, and institutional characteristics, predictors of postoperative medical resource utilization and medical outcomes were evaluated through multiple linear regression analysis and Cox regression analysis.

Results The prevalence of inguinal hernia repair per 100,000 population significantly decreased from 195.38 in 1997 to 39.66 in 2013 ($p < 0.05$). Demographic characteristics, clinical characteristics, and institutional characteristics were significantly associated with postoperative medical resource utilization and medical outcomes ($p < 0.05$). Of these characteristics, both surgeon volume and hospital volume had the strongest association.

Conclusions The inguinal hernia repair prevalence rate gradually decreased during the study period. Demographic characteristics, clinical characteristics, and institutional characteristics had strong associations with postoperative medical resource utilization and medical outcomes. Furthermore, hospital volume and surgeon volume had the strongest associations with postoperative medical resource utilization and medical outcomes. Additionally, providing the education needed to make the most advantageous medical decisions would be a great service not only to patients and their families, but also to the general population.

✉ Hon-Yi Shi
hshi@kmu.edu.tw

[1] Department of Nursing, Meiho University, Pingtung, Taiwan

[2] Department of General Surgery and Medical Research Department, E-Da Cancer Hospital, Kaohsiung, Taiwan

[3] School of Medicine, College of Medicine, I-Shou University, Kaohsiung, Taiwan

[4] Department of Anesthesiology, Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan

[5] Department of Emergency Medicine, Yunlin Chang Gung Memorial Hospital, Chang Gung University College of Medicine, Yunlin, Taiwan

[6] Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan

[7] Department of Nursing, Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan

[8] Department of Nursing, Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan

Introduction

Inguinal hernia occurs when an organ or fatty tissue is squeezed through a weak area in the muscle or connective tissue in the inguinal region. Inguinal hernia occurs mainly in males but in any age group, from infants and youths to middle-aged and elderly individuals. Surgery is the only definitive treatment option for inguinal hernia repair, which is currently among the most common surgical procedures performed in the world [1]. Although inguinal hernia widely varies in site, size, and severity, inguinal hernia repairs can be classified into to two main types: herniorrhaphy or hernioplasty. The repair is achieved by stitching the healthy ends of tissue or muscle together; the defect is repaired using a mesh patch in herniorrhaphy and without using a mesh patch in hernioplasty. Accordingly, the surgical approach must be chosen carefully to achieve the best therapeutic effects with minimal sequelae.

Previous studies of medical utilization and medical outcomes in inguinal hernia repair patients have only investigated one or several medical institutions. Few have performed comprehensive systematic analyses of large nationwide samples [1–3]. Additionally, few studies performed in Taiwan or elsewhere have used data for more than 10 years; most have analyzed data for periods as short as 6 months or 1 year [3–5]. In contrast, the current study analyzed patient data for up to 16 years. Additionally, most studies of postoperative hernia patients performed so far have only focused on a single characteristic of the patient, whereas this study systematically collected and analyzed data for several characteristics, including medical expenses, length of stay, and complications.

To fill the above gaps in the literature, this study performed a long-term, nationwide, longitudinal investigation of medical resource utilization and medical outcomes. The purpose of this study was to identify long-term trends in inguinal hernia repair and to identify predictors of medical resource utilization and medical outcomes in inguinal hernia repair patients.

[9] Department of Healthcare Administration and Medical Informatics, Kaohsiung Medical University, 100, Shih-Chuan 1st Road, Kaohsiung 80708, Taiwan

[10] Department of Business Management, National Sun Yat-Sen University, Kaohsiung, Taiwan

[11] Department of Medical Research, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan

[12] Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan

Methods

Data source and study population

The inclusion criteria were age 18 years or older and a history of open or laparoscopic inguinal hernia repair from January 1, 1997, to December 31, 2013. The diagnosis of inguinal hernia was according to International Statistical Classification of Disease and Related Health Problems, 9th edition (ICD-9-CM) codes, 550.00–550.03, 550.10–550.13, and 550.90–550.93 for inguinal hernia, and surgical National Health Insurance classification codes (75606B, 75607C, 75613C, and 75614C) for herniorrhaphy. Patients who had received other surgical procedures during the same admission were excluded. Patients were excluded if they were younger than 18 years and if their age or gender was not indicated. After disqualified patients are excluded, the final sample included 14,970 cases.

Study variables

The independent variables in this study included four demographic characteristics (age, gender, socioeconomic status, and urbanization level), one clinical characteristic (Charlson Comorbidity Index), and four institutional characteristics (hospital level, surgery type, hospital volume, and surgeon volume). Healthcare utilization refers to the use of health care services. Healthcare expenditures and length of stay (LOS) are two relatively simple measures of healthcare resource utilization by patients [6, 7]. The dependent variables included medical resource utilization variables (postoperative outpatient medical expenditures, postoperative length of stay, and total postoperative medical expenditures) and medical outcome variables (30-day readmission, 90-day readmission, incision infection, cellulitis, hematoma, and recurrence).

Statistical analysis

The unit of analysis in this study was the individual inguinal hernia repair patient. Descriptive statistics were tabulated to depict demographic, clinical, and institutional characteristics. Regarding outpatient and total medical expenditures for hospitalization, the standard administrative claims data required by the Taiwan Bureau of National Health Insurance (BNHI) included the physician diagnosis fee, ward fee, examination fee, medicine and pharmacy service fee, rehabilitation therapy fee, special material fee, and others. Medical expenditures were viewed from the perspective of the BNHI. The consumer price index was used to convert medical expenditures incurred in each year of the study from NT dollars to the equivalent 2019 US

dollars. The exchange rate for NT$ to US$ was 30.5 for year 2019. Additionally, medical expenditures in future years were discounted by 3% annually.

Multiple linear regression analysis was performed to determine the significant predictors of postoperative outpatient medical expenditures, postoperative length of stay, and total postoperative medical expenditures. Postoperative outpatient medical expenditures, postoperative length of stay, and total postoperative medical expenditures were log transformed to reduce skewness and the number of outliers and to improve the normality, linearity, and homoscedasticity of residuals. Cox proportional hazard models were also constructed to explore significant predictors of medical outcomes, including 30-day readmission, 90-day readmission, incision infection, cellulitis, hematoma, and recurrence.

Standard regression diagnostics were used to check the assumptions of the regression analyses [8]. Statistical analyses were performed using the Stata Statistical Package, version 13.0 (Stata Corp, College Station, TX). All tests were two-sided, and p values less than 0.05 were considered statistically significant.

Results

The average age of the patients in this study was 54.82 ± 16.94 years (Table 1). The percentage of males (85.1%) was higher than the percentage of females. Regarding socioeconomic status, the largest percentage of patients (52.3%) had an annual income less than NT$20,000. For residence urbanization level, the largest percentage of patients (69.5%) lived in urban areas. For hospital level, the largest percentage of patients (38.3%) had been treated at a district hospital. For surgical approach, the largest percentage of patients (96.2%) had received an open procedure. The percentages of patients readmitted 30 and 90 days after discharge were 6.4% and 11.5%, respectively. The average surgeon volume was 18.14 ± 21.26 cases, and the average hospital volume was 46.83 ± 136.82 cases.

The prevalence of inguinal hernia repair per 100,000 population significantly declined from 195.38 in 1997 to 39.66 in 2013 ($p < 0.001$) (Table 2). The prevalence of inguinal hernia repair showed a consistent declining trend throughout the 16-year period of this study. The estimated mean total postoperative medical expenditures significantly increased from $981 in 1997 to $1387 in 2013 ($p < 0.001$), which was a 41.4% increase (Fig. 1). Conversely, the mean postoperative LOS significantly decreased from 5.6 days in 1997 to 2.5 days in 2013 ($p < 0.001$), which was a 55.4% decrease.

Table 1 Characteristics of patients in the study

Variable	*N* (%)	Mean ± SD
Age		54.82 ± 16.94
Gender		
Male	12,735 (85.1%)	
Female	2235 (14.9%)	
Socioeconomic status		
< US$655.7	7833 (52.3%)	
US$655.7 ~ US$1311.4	5262 (35.2%)	
≥ US$1311.5	1875 (12.5%)	
Residence urbanization level		
Urban	10,400 (69.5%)	
Rural	4570 (30.5%)	
Charlson comorbidity index		0.31 ± 0.84
Hospital level		
Medical center	4897 (32.7%)	
Regional hospital	4345 (29.0%)	
District hospital	5728 (38.3%)	
Surgery type		
Open	14,407 (96.2%)	
Laparoscopic	563 (3.8%)	
Temporal period		
1997–2002	8019 (53.6%)	
2003–2008	4519 (30.2%)	
2009–2013	2432 (16.2%)	
30-day readmission		
No	14,005 (93.6%)	
Yes	965 (6.4%)	
90-day readmission		
No	13,248 (88.5%)	
Yes	1722 (11.5%)	
Surgeon volume		18.14 ± 21.2
Hospital volume		46.83 ± 36.8

SD Standard deviation

Table 3 shows that demographic characteristics, clinical characteristics, and institutional characteristics had statistically significant associations with postoperative outpatient medical expenditures, postoperative hospitalization days, and total postoperative medical expenditures ($p < 0.001$). In this nationwide population-based study, the overall inguinal hernia repair recurrence rate was 9.7%. The recurrence rates for laparoscopic and open inguinal hernia repairs were 12.3% and 7.8%, respectively. Furthermore, surgeon volume and hospital volume had the strongest associations with medical resource utilization.

Additionally, demographic characteristics, clinical characteristics, and institutional characteristics had a significant positive association with 30-day readmission,

Table 2 Long-term trends in prevalence of inguinal hernia repair in each period

Year	Number of inguinal hernia repair patients	Total population	Prevalence ($1/10^5$)	Change rate (%)
1997	1847	21,742,815	195.38	
1998	1473	21,928,591	154.50	− 40.88
1999	1354	22,092,387	140.96	− 13.54
2000	1193	22,276,672	123.17	− 17.79
2001	1129	22,405,568	115.90	− 7.27
2002	1023	22,520,776	104.48	− 11.42
2003	789	22,604,550	80.28	− 24.20
2004	898	22,689,122	91.03	10.75
2005	810	22,770,383	81.82	− 9.21
2006	736	22,876,527	74.00	− 7.82
2007	667	22,958,360	66.82	− 7.18
2008	619	23,037,031	61.80	− 5.02
2009	570	23,119,772	56.70	− 5.10
2010	525	23,162,123	52.13	− 4.57
2011	509	23,224,912	50.41	− 1.72
2012	425	23,315,822	41.92	− 8.49
2013	403	23,373,517	39.66	− 2.26

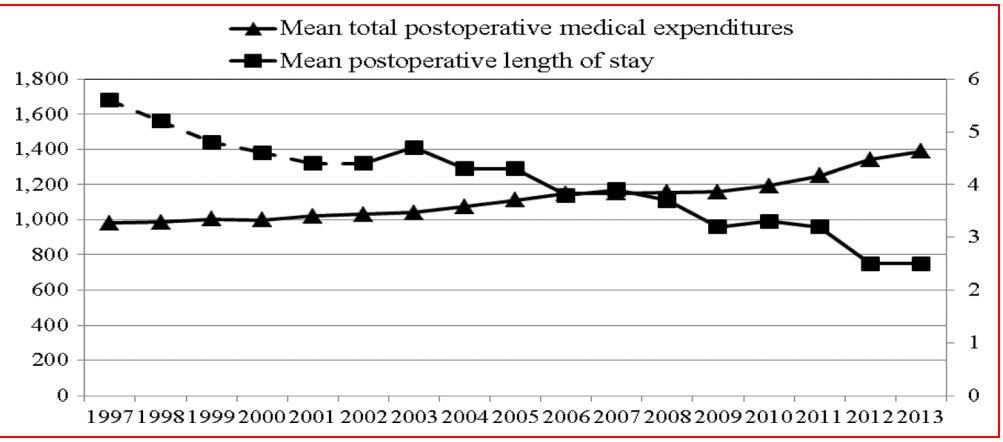

Fig. 1 Trends in mean postoperative total medical expenditures and mean postoperative length of stay for hernia repair patients during the study period

90-day readmission, incision infection, cellulitis, hematoma, and recurrence simultaneously ($p < 0.001$) (Tables 4, 5).

Discussion

The prevalence of inguinal hernia repair in Taiwan showed a significant downward trend during the study period. Several factors may have contributed to the decline in hernia repair in the study population. First, elderly patients who had been diagnosed with hernia may have undergone inguinal hernia repair in hospital but then died of another comorbidities during hospitalization [9, 10]. The prevalence rate decreased from 250.17 to 210.14 per 100,000 person-years during the study period [10]. Second, cigarette smoking, which may be a risk factor for recurrence of inguinal hernia repair, has declined in Taiwan [11]. Third, Taiwan has encountered the problem of a declining birthrate. As Table 2 indicates, the population gradually during the study period, and the prevalence per 100,000 person-years substantially decreased from 195.38 in 1997 to 39.66 in 2013. Also, youngsters with hernia were likely to refuse surgical treatment [12]. Fourth, improvements in surgical technology and socioeconomic status have gradually decreased the incidence of inguinal hernia repair recurrence [10]. The above four factors may

Table 3 Significant predictors of postoperative outpatient medical expenditures, postoperative hospitalization days, and total postoperative medical expenditures of inguinal hernia repair patients*

Variables	Postoperative outpatient medical expenditures (US$)		Postoperative length of stay		Total postoperative medical expenditures (US$)	
	Non-standardized coefficient (B)	Standardized Coefficient (Beta)	Non-standardized coefficient (B)	Standardized coefficient (Beta)	Non-standardized coefficient (B)	Standardized coefficient (Beta)
Age	0.02	0.10	0.01	0.11	0.03	0.12
Gender						
Male versus female	0.43	0.14	0.02	0.03	0.67	0.14
Residence urbanization level						
Urban versus rural	0.41	0.12	0.07	0.09	0.65	0.12
Socioeconomic status						
US$655.7 ~ NT$1311.4 versus < US$655.7	0.44	0.10	0.07	0.07	0.82	0.11
≥ US$1311.5 versus < US$655.7	0.60	0.08	0.05	0.03	1.08	0.09
Hospital level						
Regional hospital versus medical center	0.55	0.12	0.10	0.10	0.84	0.12
District hospital versus medical center	0.69	0.14	0.12	0.11	0.95	0.12
Surgery type						
Laparoscopic versus open	0.20	0.01	0.04	0.01	0.40	0.02
Charlson comorbidity index	0.02	0.01	0.10	0.15	0.03	0.01
Surgeon volume	− 0.01	− 0.24	− 0.01	− 0.27	− 0.02	− 0.24
Hospital volume	− 0.01	− 0.23	− 0.01	− 0.22	− 0.01	− 0.23

*All p values are less than 0.001

also explain the dramatically reduced prevalence of inguinal hernia repair.

This analysis of trends in inguinal hernia repair patients showed that, during the study period, mean total postoperative medical expenditures increased, but mean postoperative LOS decreased. Apparently, the increase in total postoperative medical expenditures was mainly driven by the complex interplay between case mix and the use of new medical technologies. Furthermore, patients in the present study were aged 54.8 years or older. Advances in medical technology have also increased the number of available of treatment options and have improved medical techniques and instruments, management of major treatments, and the quality of hospital care, all of which have contributed to decreases in morbidity rates, mortality rates, and LOS in inguinal hernia repair patients. Notably, however, although both of these trends have contributed to increases in treatment options and in the availability of medical resources, they have also increased total postoperative medical expenditures.

Age was the main determinant of the number of hospitalization days at the time of inguinal hernia repair. According to the documents explored, as age increased in the aged 30–70 years bracket, the number of hospitalization days increased from 194 to 684 in males and increased from 28 to 108 in females. Univariate analysis revealed that the relapse risk of inguinal hernia was highest in the youngest age group, and in the patients aged 30–39 years was 1.68 (95% CI 1.07–2.65). Nevertheless, for the patients over age 60 it was 2.76 (95% CI 1.90–3.99), which was more than that of the youngest age group. Therefore, there was a strong positive correlation between age and inguinal hernia repair [10, 13]. Well-structured simulation-based training courses and ensuring that the patients are suitable for trainees to operate on can help reduce the incidence of whole-term complications of related surgery.

Training in total extraperitoneal (TEP) herniorrhaphy and in transabdominal preperitoneal (TAPP) approach requires a large caseload in the training hospital as well as long-term supervision of trainees by experienced laparoscopic surgeons, which implies a very high cost of training for laparoscopic surgery [14–17]. Compared to open surgery, the advantages of minimally invasive surgery include better relief of pain, shorter length of stay, fewer

Table 4 Significant predictors of 30-day readmission and 90-day readmission of inguinal hernia repair patients

Variables	30-day readmission		90-day readmission	
	HR	*p* value	HR	*p* value
Age	0.99	< 0.001	0.99	< 0.001
Gender				
Male versus female	0.50	< 0.001	0.56	< 0.001
Residence urbanization level				
Urban versus rural	0.67	< 0.001	0.71	< 0.001
Socioeconomic status				
US$655.7 ~ NT$1311.4 versus < US$655.7	0.57	< 0.001	0.58	< 0.001
≥ US$1311.5 versus < US$655.7	0.37	< 0.001	0.38	< 0.001
Hospital level				
Regional hospital versus medical center	0.55	< 0.001	0.60	< 0.001
District hospital versus medical center	0.61	< 0.001	0.61	< 0.001
Surgery type				
Laparoscopic versus open	0.70	< 0.001	0.83	< 0.001
Charlson comorbidity index	1.42	< 0.001	1.44	< 0.001
Surgeon volume	0.98	< 0.001	0.98	< 0.001
Hospital volume	0.99	< 0.001	0.99	< 0.001

HR Hazards ratio

Table 5 Determinants of incision infection, cellulitis, hematoma and recurrence after inguinal hernia repair

	Incision infection		Cellulitis		Hematoma		Recurrence	
	HR	*p* value	HR	*p* value	HR	*p* value	HR	*p* value
Age	0.98	< 0.001	0.99	< 0.001	0.97	< 0.001	0.98	< 0.001
Gender								
Male versus female	0.41	< 0.001	0.59	< 0.001	0.50	< 0.001	0.93	< 0.001
Urbanization level								
Urban versus rural	0.41	< 0.001	0.58	< 0.001	0.58	< 0.001	0.54	< 0.001
Socioeconomic status								
US$655.7 ~ NT$1311.4 versus < US$655.7	0.88	< 0.001	0.96	< 0.001	0.70	< 0.001	0.62	< 0.001
≥ US$1311.5 versus < US$655.7	0.45	< 0.001	0.49	< 0.001	0.30	< 0.001	0.34	< 0.001
Hospital level								
Regional hospital versus medical center	0.30	< 0.001	0.67	< 0.001	0.19	< 0.001	0.44	< 0.001
District hospital versus medical center	0.30	< 0.001	0.73	< 0.001	0.09	< 0.001	0.50	< 0.001
Surgical type								
Laparoscopic versus open	0.52	< 0.001	0.66	< 0.001	1.33	< 0.001	1.50	< 0.001
Charlson comorbidity index	1.22	< 0.001	1.18	< 0.001	1.17	< 0.001	0.97	< 0.001
Surgeon volume	0.98	< 0.001	0.99	< 0.001	0.96	< 0.001	0.99	< 0.001
Hospital volume	0.98	< 0.001	0.99	< 0.001	0.98	< 0.001	0.99	< 0.001

complications, and more efficient medical utilization [18–20]. Laparoscopic surgical techniques and endoscopic hernia repair are included in the training received by laparoscopic surgery specialists in many countries [14]. In terms of surgical outcomes, however, the experience of the individual surgeon is better outcome predictor compared to completion of intensive training in laparoscopic surgery, which may include the use of interactive technologies,

surgical simulators, and video recording analysis and registrars reveal that the learning curve has been completed [21]. Likewise, the recurrence rate can be significantly reduced after more than 250 TEP operations compared with up to 250 TEP operations.

Socioeconomic status has a significant positive association with medical resource utilization. Inguinal hernia patients with a high socioeconomic status have the financial resources to choose between laparoscopic surgery and robotic surgery to obtain the best outcomes, e.g., postoperative hospital stay, comorbidity, pain, and other adverse reactions [22]. High surgeon volume also has a strong positive association with postoperative outpatient medical expenditures and total postoperative medical expenditures. An experienced surgeon performing an inguinal hernia repair can minimize hospital stay, comorbidity, pain, and other adverse reactions, which then reduces overall medical costs [14–17].

The introduction of laparoscopic inguinal hernia repair yielded several potential advantages: less postoperative discomfort and pain, shorter recovery time, faster return to full activity, easier repair of recurrent hernia, ability to treat bilateral hernias concurrently, ability to perform diagnostic laparoscopy concurrently, ability to ligate the hernial sac at the highest possible site, improved cosmesis, and decreased recurrence [13, 22, 23]. Potential disadvantages include complications, e.g., bowel, bladder, and vascular injuries; potential adhesive complications at sites where the peritoneum has been breached or at sites where prosthetic material has been placed; the need for a general anesthetic; and the added cost of specialized equipment needed to perform the procedure. Although laparoscopic hernia repair has a longer surgery time and shorter length of stay than open surgery (2.9 days vs. 5.1 days), the incidence of complications after laparoscopic hernia repair also shows a declining trend [23].

Some study limitations should be addressed. This study analyzed data for years 1997–2013 contained in the National Health Insurance Database. Since this study used secondary data, the research results may have been affected by data entry errors, privacy restrictions on the use of patient data, and inaccuracies in the collection and interpretation of data. Errors in the incidence and recurrence of inguinal hernias during the study period may have occurred. For example, the compiled data may have contained coding errors and data entry errors by frontline personnel. A further limitation is that the analysis was limited to patients hospitalized for inguinal hernia, whereas many inguinal hernia repairs can be completed in day surgery. During intra-operative procedures for inguinal hernia repairs in day surgery, good control of pain is important for achieving optimal hemodynamic stability and for preserving respiratory function. The high efficacy and safety of the pain drugs used in this study were evidenced by the high satisfaction of the patients. Furthermore, patients had high tolerance for the most painful tissue handling procedures (e.g., spermatic cord traction or prosthesis fixation). The pain caused by the surgical procedure was not included as a relevant factor in this study. We intend to consider pain and other factors in subsequent studies. Additionally, the data source in this study, the LHID, uses the ICD-9, which has a limited range of diagnostic and surgical procedure codes. For example, in a patient with surgical disposal code 5421 indicating the laparoscopic inguinal hernia repair, we could not determine whether the surgical treatment modality was laparoscopy or robotic surgery. This study could not accurately compare the technology costs since only a small percentage (slightly more than 3%) of the procedures were performed by laparoscopic or robotic surgery. Therefore, further studies are needed to explore factors in cost differences (e.g., the use of expensive meshes) in the procedures.

Conclusions

This study showed that, despite the growing global burden of inguinal hernia repair, high-quality nationwide population-based studies of inguinal hernia repair prevalence and outcomes are scarce. This study systematically collected and analyzed data pertaining to inguinal hernia patients, including medical expenditures, LOS, complications, and mortality. The data analysis revealed a significant decline in the prevalence of inguinal hernia repair. Moreover, healthcare providers and patients should also understand that hospital resource utilization and medical outcomes depend not only on demographic characteristics and clinical characteristics but also on institutional characteristics. For example, surgeon volume and hospital volume were critical determinants of medical resource utilization and medical outcomes. Similar population-based studies of inguinal hernia repair prevalence, costs, and outcomes in other populations are urgently needed to establish reliable surveillance systems for monitoring and evaluating intervention strategies, for implementing evidence-based healthcare planning, and for developing effective treatment, prevention, and education strategies.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study protocol was approved by the Institutional Review Board of Kaohsiung Medical University Hospital (KMUH-IRB-2019067).

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