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Predictors of laparoscopic versus open inguinal hernia repair

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Abstract

Background Inguinal hernia repair (IHR) is among the most common general surgery procedures. Multiple studies have examined costs and benefits of laparoscopic approach versus open repair. This study aimed to identify patient, surgeon, and hospital demographic predictors of laparoscopic versus open IHR.

Methods We conducted a retrospective analysis of 342,814 IHRs (241,669 open; 101,145 laparoscopic) performed in adults (age ≥ 18) from 2010 to 2015 using the Premier Hospital Database. Multivariate logistic regression was used to estimate the adjusted odds ratio of an IHR being laparoscopic versus open with respect to several demographic variables.

Results The odds of an IHR being laparoscopic increased from 2010 to 2015. A laparoscopic procedure was more likely in patients who were < age 65 (OR 1.29, CI 1.24–1.31, $p < 0.0001$), male (OR 1.31, CI 1.27–1.34, $p < 0.0001$), privately insured (OR 1.36, CI 1.33–1.40, $p < 0.0001$), and neither white, black, nor Hispanic (OR 1.11, CI 1.09–1.14, $p < 0.0001$). The likelihood of a procedure being laparoscopic decreased 13% with each one-unit increase in Charlson comorbidity index value (OR 0.88, CI 0.87–0.89, $p < 0.0001$). Surgeons were more likely to perform a laparoscopic procedure if they had larger annual IHR caseloads (≥ 45/year; OR 1.57, CI 1.53–1.60, $p < 0.0001$), and operated at large hospitals (> 500 beds; OR 1.36, CI 1.33–1.39, $p < 0.0001$) in New England (OR 2.38, CI 2.29–2.47, $p < 0.0001$). Non-predictors of a laparoscopic procedure included urban/rural hospital location (OR 1.02, CI 0.10–1.05, $p = 0.06$) and hospital teaching status (OR 1.01, CI 0.99–1.03, $p = 0.2084$).

Conclusions Use of laparoscopic IHR is increasing. Patient age, gender, race, and insurance type, as well as surgeon annual volume, hospital size, and hospital region were predictors of a laparoscopic procedure. Further studies are needed to explain and remedy underlying differences impacting these predictors.

Keywords Inguinal hernia · Minimally invasive surgery · Laparoscopic IHR · Open IHR · Demographics

Inguinal hernia repair (IHR) is among the most commonly performed general surgery procedures [1]. Inguinal hernias account for up to 75% of all abdominal wall hernias [2]. IHR has traditionally been an open operation, but since laparoscopic inguinal hernia management was first reported in the early 1990s [3], laparoscopic IHR has continued to be improved and applied. Also within this time period, multiple teams have investigated the costs and benefits of laparoscopic versus open IHR, examining factors including direct and societal costs of operation, operation duration, post-operative pain and numbness, post-operative recovery time, surgical complications, and post-operative recurrence, as well as the association between surgeon case volume/experience and surgical outcomes [4]. Through these studies, laparoscopic IHR has been established as safe and effective [4].

The use of open IHR continues to exceed the use of a laparoscopic approach. This has been largely attributable to conflicting reports regarding recurrence rate, post-operative complications and cost associated with the laparoscopic approach [5, 6]. The effects of other factors such as patient, surgeon, and hospital demographic characteristics in the

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decision to employ laparoscopic versus open IHR are less understood. The purpose of this study was to identify predictors of laparoscopic versus open IHR based on patient, surgeon, and hospital demographics.

Materials and methods

Patient selection

342,814 outpatient encounters between 2010 and 2015 with a CPT code for IHR were identified using the Premier Hospital Database. Patient selection was limited to patients ≥ 18 years old on the day of surgery with complete demographic information who did not have a CPT code "S2900", indicating robotic surgery. Included were 241,669 patients who underwent an open IHR and 101,145 who received a laparoscopic IHR.

Statistical analysis

Multivariate logistic regression was used to estimate the adjusted odds ratio of a procedure being performed laparoscopically versus open with respect to several demographic variables. The variables studied include age, gender, race, insurance type, Charlson comorbidity index (CCI), year of surgery, physician experience, hospital region, hospital teaching status, hospital size, and CMS urban/rural designation. Statistical significance was defined as $p < 0.05$. SAS software version 9.4 was used for statistical analysis.

Results

A total of 342,814 IHRs were analyzed. 241,669 (70.5%) IHRs were open, and 101,145 (29.5%) IHRs were laparoscopic.

Year of surgery

The rate of laparoscopic IHR increased each year from 2010 to 2015 (Table 1). The rate of laparoscopic IHR increased by approximately 2% each year from 24.25% in 2010 to 34.87% in 2015. There was a significant association between the rate of laparoscopic IHR and the year of surgery ($p < 0.0001$). The adjusted odds ratio of an IHR being performed laparoscopically in a given year relative to an IHR being performed in 2010 increased steadily from 1.13 (CI 1.10–1.16, $p < 0.0001$) in 2011 to 1.74 (CI 1.69–1.79, $p < 0.0001$) in 2015 (Fig. 1).

Table 1 Procedures per year

Years	Open		Laparoscopic		*p*-value*
	$N = 241{,}669$		$N = 101{,}145$		
	N	%	N	%	
2010	37,400	75.75	11,973	24.25	< 0.0001
2011	41,936	73.54	15,090	26.46	
2012	44,777	71.53	17,818	28.47	
2013	42,967	69.54	18,823	30.46	
2014	40,080	67.88	18,968	32.12	
2015	34,509	65.13	18,473	34.87	

*Chi square test, significant at $p < 0.05$

Patient demographics

The rate of laparoscopic IHR in patients younger than 65 years of age was 32.81%, and the rate in patients older than or equal to 65 was 23.73% (Table 2). There was a significant association between the rate of laparoscopic IHR and patient age ($p < 0.0001$). Patients younger than 65 were more likely to receive a laparoscopic IHR (OR 1.28, CI 1.24–1.31, $p < 0.0001$) (Fig. 2).

The Charlson comorbidity index (CCI) for laparoscopic procedures was 0.24 ± 0.63 (mean ± SD) and for open procedures was 0.34 ± 0.78. There was a significant association between the rate of laparoscopic IHR and CCI ($p < 0.0001$). The rate of laparoscopic IHR decreased 13% with each one-unit increase in CCI (OR 0.88, CI 0.87–0.89, $p < 0.0001$) (Fig. 2).

The rate of laparoscopic IHR in male patients was 30.05%, and the rate in female patients was 23.73% (Table 2). There was a significant association between the rate of laparoscopic IHR and gender ($p < 0.0001$). Male patients were more likely to receive a laparoscopic IHR (OR 1.31, CI 1.27–1.35, $p < 0.0001$) (Fig. 2).

The rate of laparoscopic IHR was 23.60% in black patients, 20.92% in Hispanic patients, 29.96% in other race patients, and 29.99% in white patients (Table 2). There was a significant association between the rate of laparoscopic IHR and race by univariate analysis ($p < 0.0001$). Relative to white patients, black patients (OR 0.74, CI 0.72–0.77, $p < 0.0001$) and Hispanic patients (OR 0.88, CI 0.79–0.97, $p = 0.0091$) were less likely to receive a laparoscopic IHR. Other race patients had a similar absolute rate of laparoscopic IHR to white patients (29.96% vs. 29.99%), however, after adjusting for other factors, other race patients were found to be more likely to receive a laparoscopic IHR when compared to white patients by multivariate analysis (OR 1.11, CI 1.09–1.14, $p < 0.0001$) (Fig. 2).

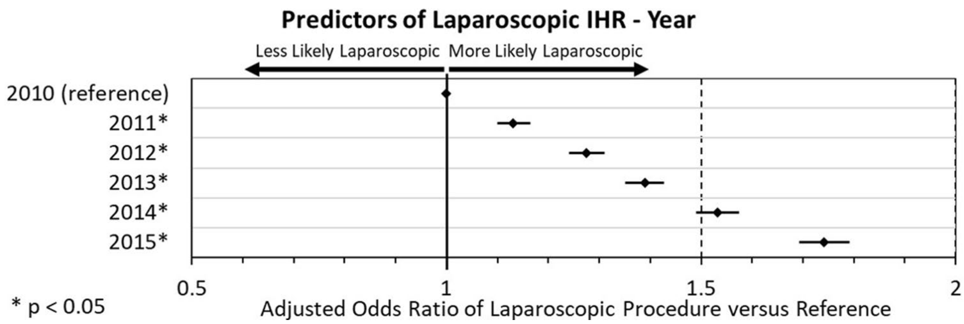

Fig. 1 Odds ratio of laparoscopic IHR versus reference group for year of surgery. *Multivariable logistic regression model, significant at $p<0.05$

Table 2 Patient demographics

	Open		Laparoscopic		*p*-value*
	N = 241,669		*N* = 101,145		
	N	%	*N*	%	
Age (years)					
<65	146,606	67.19	71,575	32.81	<0.0001
≥65	95,063	76.27	29,570	23.73	
Gender					
Male	219,127	69.95	94,132	30.05	<0.0001
Female	22,542	76.27	7013	23.73	
Race					
Black	16,934	76.40	5232	23.60	<0.0001
Hispanic	2000	79.08	529	20.92	
Other	35,144	70.04	15,036	29.96	
White	187,591	70.01	80,348	29.99	
Insurance					
Medicaid	14,579	73.25	5325	26.75	<0.0001
Managed Care	109,921	65.36	58,250	34.64	
Uninsured	10,547	78.18	2943	21.82	
Other	15,377	69.27	6823	30.73	
Medicare	91,245	76.64	27,804	23.36	

*Chi square test, significant at $p<0.05$

The rate of laparoscopic IHR was 26.75% in patients with Medicaid, 34.64% in patients with managed care, 21.82% in uninsured patients, 30.73% in patients with other types of insurance, and 23.36% in patients with Medicare (Table 2). There was a significant association between the rate of laparoscopic IHR and insurance type ($p<0.0001$). Uninsured patients were less likely to receive a laparoscopic IHR than patients with Medicare (OR 0.78, CI 0.75–0.83, $p<0.0001$). Medicaid patients were no more or less likely to receive a laparoscopic IHR when compared to Medicare patients (OR 0.97, CI 0.93–1.01, $p=0.0972$). Relative to patients with Medicare, patients with managed care (private insurance) (OR 1.36, CI 1.33–1.40, $p<0.0001$) and other insurance (OR 1.13, CI 1.09–1.18, $p<0.0001$) were more likely to receive a laparoscopic IHR (Fig. 2).

Surgeon volume

The rate of laparoscopic IHR increases as surgeon annual IHR case volume increases (Table 3). The rate of laparoscopic IHR was 24.11% in surgeons with ≤15 cases/year, and 35.21% in surgeons with ≥45 cases/year. There was a significant association between the rate of laparoscopic IHR and surgeon annual case volume ($p<0.0001$).

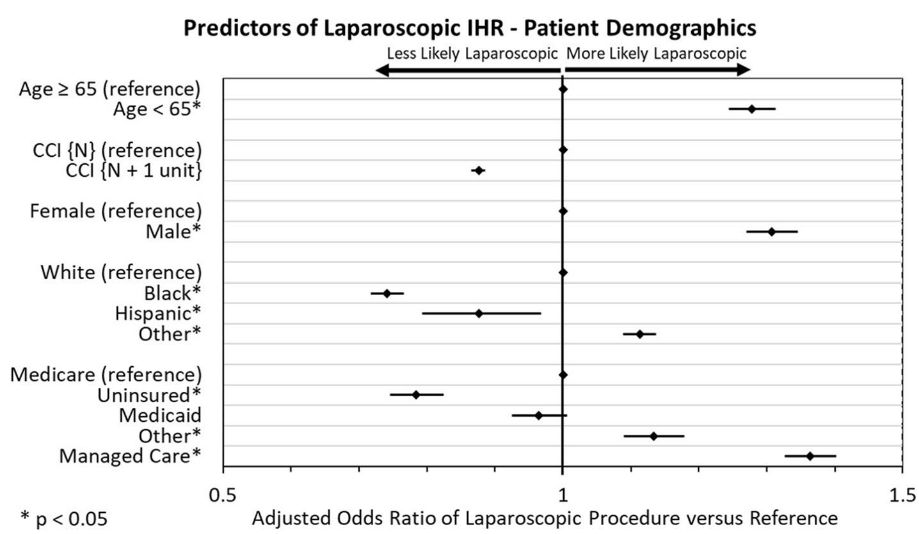

Fig. 2 Odds ratio of laparoscopic IHR versus reference group for patient demographics. *Multivariable logistic regression model, significant at $p<0.05$

Table 3 Surgeon volume

Volume (cases/year)	Open		Laparoscopic		*p*-value*
	N = 241,669		N = 101,145		
	N	%	N	%	
≥ 45	64,299	64.79	34,941	35.21	< 0.0001
30–44	49,129	71.02	20,051	28.98	
16–29	64,800	71.37	25,994	28.63	
≤ 15	63,441	75.89	20,159	24.11	

*Chi square test, significant at $p < 0.05$

Compared to surgeons with an annual volume of ≤ 15 cases, surgeons with an annual volume of 16–29 cases (OR 1.22, CI 1.19–1.24, $p < 0.0001$), 30–44 cases (OR 1.20, CI 1.19–0.124, $p < 0.0001$), and ≥ 45 cases (OR 1.57, CI 1.53–1.60, $p < 0.0001$) were more likely to perform a laparoscopic IHR (Fig. 3).

Hospital characteristics

The rate of laparoscopic IHR was 30.41% at teaching hospitals and 28.99% at non-teaching hospitals (Table 4). There was a significant association between the rate of laparoscopic IHR and teaching hospital status by univariate analysis ($p < 0.0001$). However, after adjusting for other factors, procedures performed at teaching hospitals were found to be no more or less likely to be laparoscopic than procedures performed at non-teaching hospitals by multivariate analysis (OR 1.01, CI 0.99–1.03, $p = 0.2084$) (Fig. 4).

The rate of laparoscopic IHR was 34.65% at hospitals with > 500 beds, 28.05% at hospitals with 300–500 beds, and 27.98% at hospitals with < 300 beds (Table 4). There was a significant association between the rate of laparoscopic IHR and hospital bed size by univariate analysis ($p < 0.0001$). Hospitals with > 500 beds were more likely than hospitals with < 300 beds to perform laparoscopic IHR (OR 1.36, CI 1.33–1.39, $p < 0.0001$). Hospitals with 300–500 beds had a higher absolute rate of laparoscopic IHR than hospitals with < 300 beds (28.05% vs. 27.98%), however, after adjusting for other factors, hospitals with 300–500 beds were found to be less likely than hospitals with < 300 beds to perform laparoscopic IHR by multivariate analysis (OR 0.97, CI 0.96–0.99, $p = 0.0043$) (Fig. 4).

Table 4 Hospital characteristics

	Open		Laparoscopic		*p*-value*
	N = 241,669		*N* = 101,145		
	N	%	N	%	
Teaching					
Teaching	86,208	69.59	37,668	30.41	< 0.0001
Non-teaching	155,461	71.01	63,477	28.99	
Bed size					
> 500	50,466	65.35	26,760	34.65	< 0.0001
300–500	80,384	71.95	31,335	28.05	
< 300	110,819	72.02	43,050	27.98	
Urban/rural					
Urban	206,184	70.36	86,862	29.64	< 0.0001
Rural	35,485	71.30	14,283	28.70	
Region					
New England	10,809	57.29	8,057	42.71	< 0.0001
East South Central	15,323	67.28	7,451	32.72	
South Atlantic	69,857	68.13	32,672	31.87	
East North Central	37,095	69.92	15,957	30.08	
Mountain	14,315	72.01	5,565	27.99	
West North Central	13,424	72.07	5,202	27.93	
Middle Atlantic	22,686	74.07	7,940	25.93	
West South Central	20,807	75.62	6,710	24.38	
Pacific	37,353	76.32	11,591	23.68	

*Chi square test, significant at $p < 0.05$

The rate of laparoscopic IHR was 29.64% at urban hospitals and 28.70% at rural hospitals (Table 4). There was a significant association between the rate of laparoscopic IHR and hospital setting by univariate analysis ($p < 0.0001$). However, after adjusting for other factors, procedures performed at urban hospitals were found to be no more or less likely to be laparoscopic than procedures performed at rural hospitals by multivariate analysis (OR 1.02, CI 1.00–1.05, $p = 0.0627$) (Fig. 4).

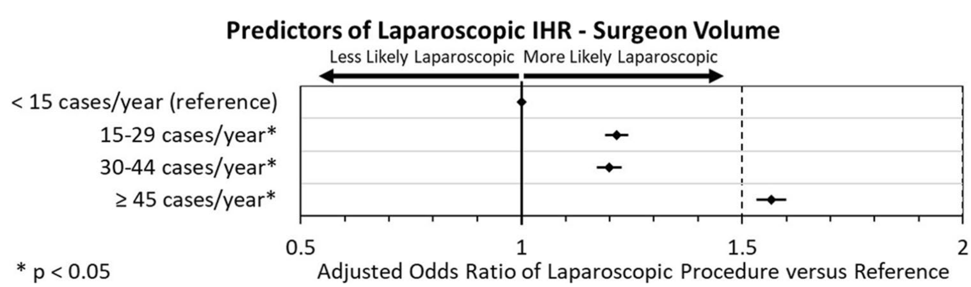

Fig. 3 Odds ratio of laparoscopic IHR versus reference group for surgeon volume. *Multivariable logistic regression model, significant at $p < 0.05$

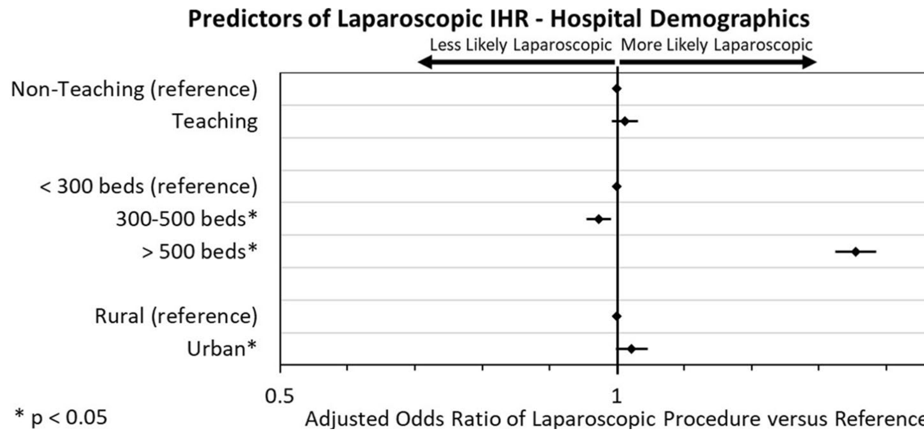

Fig. 4 Odds ratio of laparoscopic IHR versus reference group for hospital demographics. *Multivariable logistic regression model, significant at $p < 0.05$

The rate of laparoscopic IHR by region is depicted in Table 4 and Fig. 5. The rate of laparoscopic IHR was greatest in the New England region (42.71%) and lowest in the Pacific region (23.68%). There was a significant association between the rate of laparoscopic IHR and hospital region ($p < 0.0001$). The adjusted odds ratio of an IHR being performed laparoscopically in a given region relative to an IHR being performed in the Pacific region ranged from 1.18 (CI 1.14–1.22, $p < 0.0001$) in the West South Central region to 2.38 (CI 2.29–2.47, $p < 0.0001$) in the New England region (Fig. 6).

Discussion

Laparoscopy has revolutionized the practice of general surgery. Following the development of the video-assisted laparoscope in the 1970s and the first laparoscopic appendectomy in 1982, the rate of adoption of laparoscopic techniques by general surgeons has been rapid and nearly universal [7, 8]. The laparoscopic approach has become the standard of care for many general surgery procedures including cholecystectomy, appendectomy, and gastric bypass [8]. However, this has not been the case for IHR despite the fact that laparoscopic techniques for this procedure were developed in the late 1980s [7]. Our study found that in 2015 only 38% of IHRs were performed laparoscopically, which is significantly lower than the > 90% rate seen with other general surgery procedures [8]. There are two strong explanations for this. First, the learning curve for laparoscopic IHR, which has been estimated to be between 60 and 250 cases [9, 10], is associated with a higher rate of recurrence and major complications [4]. Second, early reports presented conflicting data about the efficacy of laparoscopic IHR. In 2004, Neumayer et al. reported the results of a prospective randomized trial of 2164 patients comparing laparoscopic

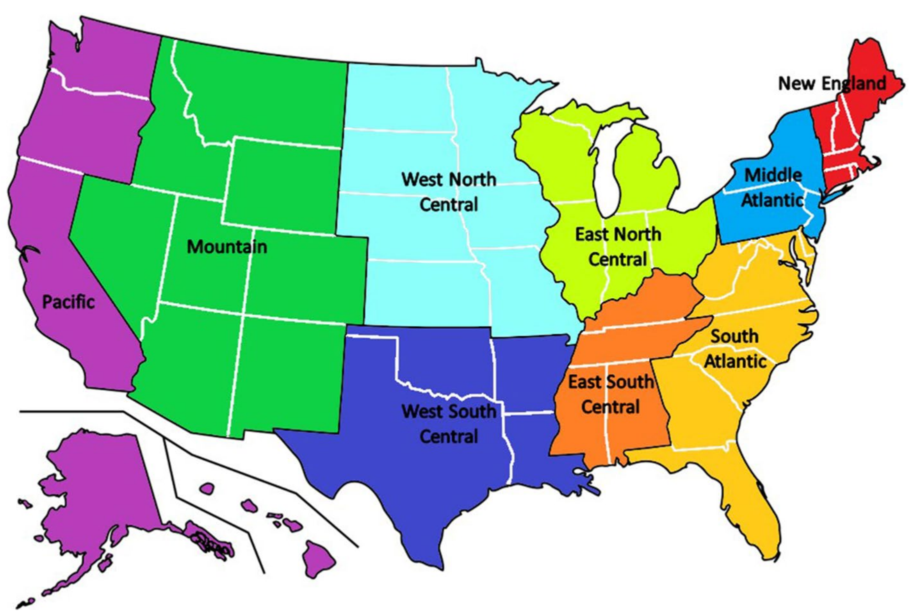

Fig. 5 Hospital regions. Purple = Pacific, Green = Mountain, Light Blue = West North Central, Dark Blue = West South Central, Lime = East North Central, Orange = East South Central, Red = New England, Blue = Middle Atlantic, Gold = South Atlantic. (Color figure online)

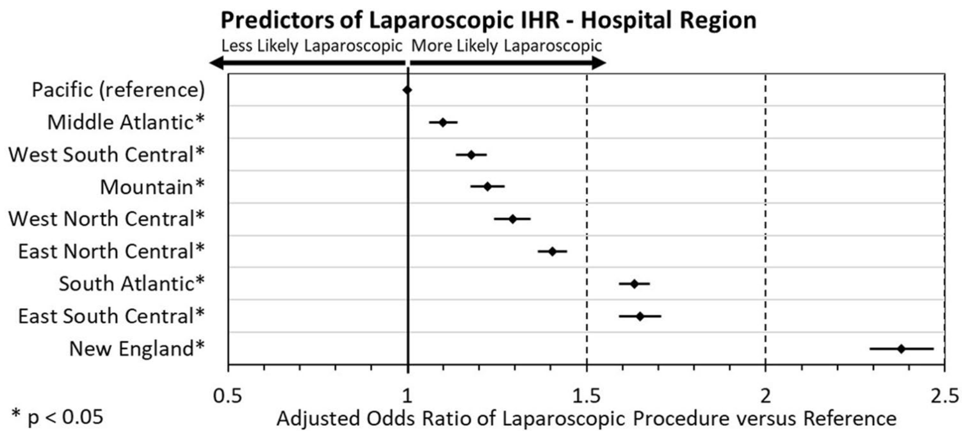

Fig. 6 Odds ratio of laparoscopic IHR versus reference group for hospital region. *Multivariable logistic regression model, significant at $p < 0.05$

and open IHR in the New England Journal of Medicine [10]. They found a higher rate of recurrence in the laparoscopic group (10.1% vs. 4.9%) and concluded that the open approach was superior. However, in the preceding year, two large meta-analyses were published that found no difference in efficacy or safety between laparoscopic and open IHR [11, 12].

Much has changed since the early reports of laparoscopic IHR. With respect to hernia recurrence, laparoscopic IHR is now considered to be equivalent to open IHR [4]. Laparoscopic IHR is associated with shorter length of stay, less pain and numbness, lower surgical site infection rates, less seroma and hematoma formation, and faster recovery to normal activity [4, 6, 13]. An additional technical advantage of laparoscopic IHR is the ability to examine and potentially repair a misdiagnosed ipsilateral femoral hernia or an occult contralateral groin hernia without additional procedures or incisions [4, 6, 14, 15]. Accordingly, the reported rate of laparoscopic IHR has gradually increased from approximately 14% in 2003 to approximately 26% in 2011 [16–22]. The results presented in the current study are in line with previously reported data and confirm that this trend has persisted with 35% of IHRs being performed laparoscopically in 2015.

Laparoscopic IHR is both safe and effective in elderly patients (> 65 years old) [4, 22]. This remains true in elderly patients with co-morbidities or an ASA class of III or IV [22]. Elderly patients may experience less pain from laparoscopic IHR than the general population [23]. However, elderly patients are less likely than the general population to receive a laparoscopic IHR [24]. Our data confirm this discrepancy. A major advantage of open IHR over laparoscopic IHR is the ability to perform the procedure without muscle relaxant. In fact, open IHR can be performed with local anesthesia and sedation. This is an appealing reason to offer open IHR to elderly patients who would tend to have a decreased tolerance for the general anesthetic and pneumoperitoneum required for laparoscopic IHR.

Laparoscopic IHR is also both safe and effective in female patients [25]. Being that the rate of femoral hernia is higher in females, the laparoscopic approach has been recommended as the preferred approach for female patients [15]. Previous reports have shown higher, lower, and similar rates of laparoscopic IHR in females versus males [17, 21, 24]. Despite recommendations to the contrary, our study found that females were less likely to receive a laparoscopic IHR than males. A proposed explanation for this is that females may be more likely to choose open IHR for cosmetic reasons. The incisions for a laparoscopic procedure are necessarily placed across the mid abdomen whereas as the incision for an open IHR can be hidden below the pant line. Moreover, the incision for an open IHR in a female can be made smaller than in an equivalently sized male as the surgeon does not need to dissect out the spermatic cord.

Little has been reported about the rate of laparoscopic IHR with respect to race. A study looking at the state of Florida in 2002 and 2003 found that white patients were more likely to have a laparoscopic IHR [17]. Our findings are similar. We found that white patients were more likely than black and Hispanic patients to receive a laparoscopic IHR. However, we also found that white patients were less likely than other races to receive a laparoscopic IHR. The reasons for this are unclear.

Given the cost differential of laparoscopic versus open IHR [6], it is not unexpected that insurance type influences the rate of laparoscopic IHR. Previous studies have reported that patients with private insurance are more likely to receive a laparoscopic IHR [17]. Our results support this notion in that patients with managed care (private) insurance plans were more likely to receive a laparoscopic IHR than any other insurance type.

Laparoscopy requires pneumoperitoneum, which is associated with temporary deleterious hemodynamic effects. For this reason, many surgeons will avoid laparoscopy in physiologically fragile patients. It is not surprising then that we found a lower rate of laparoscopy in patients with higher CCIs.

Low annual laparoscopic IHR volume (< 25 cases/year) is associated with a higher rate of recurrence and more post-operative pain [26]. On the other hand, the higher annual volume is associated with fewer complications and better long-term outcomes [27]. Fortunately, we found that IHR procedures performed by higher volume surgeons were more likely to be laparoscopic than IHRs performed by lower volume surgeons.

Larger hospitals (> 500 beds) were more likely to perform laparoscopic IHR than small hospitals (< 300 beds). This is presumed to be because of the greater resources necessary to conduct a laparoscopic procedure versus an open procedure. Our study found that there is no difference in laparoscopic IHR rate with respect to teaching/non-teaching status or rural/urban status. We also found that the rate of laparoscopic IHR varies greatly with respect to geographic region. The reasons for this are likely to be complex and are certainly not captured by the current study.

This study has several limitations. It is limited by its retrospective nature, which precludes any causality conclusions. This is not problematic being that our study did not attempt to link any outcomes to causes. The data examined in this study are from an administrative database. This is typically considered a flawed data source for clinical data. However, since we examined exclusively demographic data points rather than clinical data points, we consider this data source to be adequate for the current study. Finally, no outcomes were examined in this study. This may have allowed us to make more powerful conclusions about the clinical relevance of the differences discovered.

The rate of laparoscopic IHR is increasing, and it is reasonable to expect this trend to continue until the majority of IHRs are performed laparoscopically. This study found that younger age, male gender, race other than white, black or Hispanic, private insurance, CCI, higher surgeon annual volume, larger hospital size, and hospital region were predictors of laparoscopic IHR. Further studies are needed to explain why these differences exist and how they might be remedied.

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Compliance with ethical standards

Disclosures Data from the Premier Hospital Database was purchased by Medtronic, Inc. and donated for use in this research project. K. Keano Pavlosky, John D. Vossler, Sarah M. Murayama, Kenric M. Murayama have no conflict of interest or financial ties to disclose. Marilyn A. Moucharite: Employed by Medtronic, Inc. Dean J. Mikami: Consultant for Medtronic, Inc.

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