Surgical Endoscopy (2019) 33:486–493
https://doi.org/10.1007/s00464-018-6322-x

Surgeon utilization of minimally invasive techniques for inguinal hernia repair: a population-based study

Joceline V. Vu[1,2] · Vidhya Gunaseelan[1,3] · Greta L. Krapohl[1,3] · Michael J. Englesbe[1,3] · Darrell A. Campbell Jr.[1,3] · Justin B. Dimick[1,2] · Dana A. Telem[1,2]

Received: 18 May 2018 / Accepted: 29 June 2018 / Published online: 9 July 2018

Abstract

Background MIS utilization for inguinal hernia repair is low compared to in other procedures. The impact of low adoption in surgeons is unclear, but may affect regional access to minimally invasive surgery (MIS). We explored the impact of surgeon MIS utilization in inguinal hernia repair across a statewide population.

Methods We analyzed 6723 patients undergoing elective inguinal hernia repair from 2012 to 2016 in the Michigan Surgical Quality Collaborative. The primary outcome was surgeon MIS utilization. The geographic distribution of high MIS-utilizing surgeons was compared across Hospital Referral Regions using Pearson's Chi-squared test. Hierarchical logistic regression was used to identify patient and hospital factors associated with MIS utilization.

Results Surgeon MIS utilization varied, with 58% of 540 surgeons performing no MIS repair. For the remaining surgeons, MIS utilization was bimodally distributed. High-utilization surgeons were unevenly distributed across region, with corresponding differences in regional MIS rate ranging from 10 to 48% ($p < 0.001$). MIS was used in 41% of bilateral and 38% of recurrent hernia. MIS repair was more likely with higher hospital volume and less likely for patients aged 65+ (OR 0.68, $p = 0.003$), black patients (OR 0.75, $p = 0.045$), patients with COPD (OR 0.57, $p < 0.001$), and patients in ASA class > 3 (OR 0.79 $p < 0.001$).

Conclusions MIS utilization varies between surgeons, likely driving differences in regional MIS rates and leading to guideline-discordant care for patients with bilateral or recurrent hernia. Interventions to reduce this practice gap could include training programs in MIS repair, or regionalization of care to improve MIS access.

Keywords Inguinal hernia repair · Laparoscopy · Surgical technology · Robotic inguinal hernia repair · Minimally invasive surgery · Surgical disparity

Adoption of minimally invasive surgery (MIS) in inguinal hernia repair remains low, accounting for 20–25% of all inguinal hernia repairs in the United States [1–3]. MIS has advantages compared to open repair regarding return to work, postoperative pain, and chronic groin pain, making its underutilization relevant to clinical and patient-centered outcomes [4–11]. While controversy may exist for unilateral hernia, the benefit of MIS over open repair is recognized for patients with bilateral or recurrent inguinal hernias, and current guidelines recommend MIS repair for these cases [12–14]. Nevertheless, MIS utilization in inguinal hernia repair lags behind rates for operations in colorectal, gynecologic, thoracic, bariatric, and general surgery [15, 16].

The mechanisms underlying low adoption of MIS in inguinal hernia repair may be mediated by surgeon practice patterns, but it is unclear how differences in surgeon practice affect delivery of MIS on a population level. Low adoption of MIS may be due to variation in utilization within surgeons—surgeons may use MIS in only a fraction of repairs, resulting in underutilization overall. Conversely, variation may exist primarily between surgeons, with a fraction of surgeons performing MIS repair. This distinction

✉ Joceline V. Vu
vuj@med.umich.edu

[1] Department of Surgery, University of Michigan, 2800 Plymouth Road, Building 16, 1st Floor, Ann Arbor, MI 48109, USA

[2] Center for Healthcare Outcomes and Policy, Ann Arbor, MI 48109, USA

[3] Michigan Surgical Quality Collaborative, Ann Arbor, MI 48109, USA

has implications on strategies to increase MIS adoption, and also may impact whether guideline-concordant care is being delivered appropriately to patients with bilateral or recurrent hernias. Surgeon practice may also interact with patient, hospital, and geographic factors, but no prior work has examined this question across a population.

In this study, we characterized surgeon practice patterns for inguinal hernia repair in a population using data from the Michigan Surgical Quality Collaborative, a statewide clinical registry. We also quantified the use of MIS in bilateral and recurrent hernia repair. We hypothesized that variation in MIS utilization would primarily be between surgeons, and this practice variation would create disparity in MIS between geographic regions.

Methods

Overview

This retrospective cohort study included patients undergoing elective inguinal hernia repair from 2012 to 2016 in the Michigan Surgical Quality Collaborative (MSQC). The MSQC is a 72-hospital regional collaborative quality improvement program that collects 30-day outcomes and healthcare utilization for general surgery, vascular surgery, and gynecology. Participating hospitals receive funding from Blue Cross and Blue Shield of Michigan (BCBSM), a large payer in the state, to employ a trained nurse reviewer for chart review and data abstraction. Approximately 90% of eligible hospitals in Michigan, most of them community hospitals, participate in the MSQC, representing approximately 50,000 Michigan patients a year. Cases are collected in a standardized fashion according to an established algorithm to minimize selection bias and audited regularly to ensure validity. Sampled cases are weighted according to the total number of cases in the population [17].

As determined by the University of Michigan Institutional Review Board (IRB), MSQC data has patient identifiers removed, and this study was considered 'Not Regulated.'[17, 18].

Study population

The study period was January 1, 2012–December 31, 2016. We included patients above age 18 undergoing elective open and MIS inguinal hernia repair from 2012 to 2016 (CPT codes 49505, 49520, 49525, 49650, and 49651). Urgent and emergent cases and operations for strangulation or gangrene were excluded. Bilateral cases were defined as inguinal hernia repair operations that had another inguinal hernia repair CPT code listed as a concurrent procedure. For recurrent cases (CPT codes 49520, 49651), no information about the approach of the previous repair was available.

Outcome and explanatory variables

The outcome of interest was MIS utilization rate of each individual surgeon, calculated as the number of MIS repairs over total repairs performed. For a secondary analysis at the patient level, the outcome of interest was the likelihood of receiving MIS repair. Patient-level covariates included age (< 45, 45–64, 65+ years), sex, race (white, black, other), insurance type (private, Medicare, Medicaid, self-pay, uninsured, and other), obesity (BMI > 30 kg/m^2), tobacco use within 1 year, history of alcohol abuse, functional status, ASA classification, diabetes, chronic obstructive pulmonary disease, hypertension, congestive heart failure, peripheral vascular disease, ascites, history of corticosteroid therapy, and > 10% body weight loss. Hospital-level covariates included bed size and teaching status.

Analysis

First, descriptive statistics were used to characterize the utilization of MIS repair by individual surgeons. We then compared the distribution of high-utilization surgeons (defined as MIS utilization of 75% or higher) across six geographic regions with Pearson's Chi-squared test. To define geographic regions in Michigan, we used the 2010 Hospital Referral Regions (HRRs) from the Dartmouth Atlas of Heath Care [19]. HRRs are geographic regions that represent where patients are referred for major cardiovascular surgical and neurosurgical procedures, using Medicare data. They reflect regional referral areas for tertiary healthcare and have been used to study healthcare utilization. Each HRR contains at least one city where major cardiovascular surgery and neurosurgery operations are performed. In this cohort, there were a low number of hospitals in some HRRs. In order to preserve hospital anonymity, certain HRRs were merged, with the Detroit, Grand Rapids, and Traverse City/Upper Peninsula (UP) regions containing more than one HRR.

Descriptive statistics were used to quantify use of MIS and open technique in subpopulations (bilateral and recurrent hernias). We then performed a secondary analysis using a hierarchical logistic regression model to identify patient characteristics, hospital attributes, and region associated with the risk-adjusted likelihood of receiving MIS, using the patient- and hospital-level covariates listed above. As patients are clustered within hospitals, a hierarchical model allowed us to control for patient factors as well as hospital-level clustering of patients. Our model included all patient and hospital covariates with a Pearson's Chi-squared test

result of $p < 0.10$. All analyses were performed using StataSE version 14 (College Station, Texas).

Results

Characteristics of the Cohort

Between 2012 and 2016, a total of 6723 inguinal hernia repairs that met inclusion criteria were identified, representing 60% of eligible cases within the state. In total, patients from 72 hospitals and 540 surgeons were included in this analysis. The overall rate of MIS repair across the cohort was 26% (1586). Demographic data stratified between open and MIS hernia repair are shown in Table 1. The age distribution between the two groups was different, with a higher proportion of young (ages 18–44 and 45–64) patients receiving MIS repair. A higher proportion of white patients received MIS repair, and patients also differed with respect to COPD, hypertension, and ASA class.

Surgeon variation in MIS utilization

Out of the 540 surgeons included in the analysis, 58% (313) performed no MIS inguinal hernia repairs. For the remaining 227 surgeons, MIS utilization had a bimodal distribution, and 31% (71) of these surgeons had MIS utilization of 75% or greater (Fig. 1). Of the MIS repairs, 75% were performed by 14% of surgeons.

Geographic variation in surgeon practice and MIS utilization

The 71 high-utilization surgeons were not equitably distributed across the state. We examined the distribution of the high-utilization surgeons across the six geographic regions, and found significant differences in the percent of high-utilization surgeons. The Ann Arbor region had the highest percent of high-utilization surgeons (22%, or 11 out of 49 surgeons). In the Traverse City/UP region, 6 out of 32 surgeons (19%) were high-utilization surgeons, compared to 40 out of 266 surgeons (15%) in the Detroit region, 1 out of 38 (3%) in the Saginaw region, or 1 out of 45 surgeons in the Lansing region (2%, $p < 0.014$). The percent of high-utilization surgeons for each region is shown in Fig. 2.

Across six geographic regions, the risk-adjusted rate of MIS inguinal hernia repair ranged from 10 to 48% ($p < 0.001$) (Fig. 2). Regions with high rates of MIS, such as Ann Arbor or Traverse City/UP, corresponded to regions with higher percentages of high-utilization surgeons. The Traverse City/UP region had the highest MIS utilization. This region encompasses the predominantly rural HRRs in Northern Michigan and the Upper Peninsula. The regions with the lowest rates were Saginaw and Lansing (10.2 and 14.5% respectively), corresponding to the lowest percentages of high-utilization surgeons. The Grand Rapids, Detroit, and Ann Arbor HRRs had MIS rates of 23, 28, and 29% respectively.

MIS utilization for bilateral and recurrent hernias

Within the cohort, 10% (680) were recurrent hernias, and 0.7% (51) were bilateral. In bilateral and recurrent hernias, 41% (21) and 38% (258) were performed with MIS respectively.

Patient and hospital factors associated with MIS utilization

On multivariate regression analysis controlling for clinical, demographic, and geographic factors, we found that patients with COPD (OR 0.57, $p < 0.001$) and in American Society of Anesthesiologists Class III and IV (OR 0.79, $p = 0.013$) were less likely to undergo MIS repair (Table 2). Medicare patients had lower rate of MIS repair compared to privately insured patients (OR 0.79, $p = 0.032$), and there were no other differences by insurance type. Age and race were also associated with the likelihood of receiving MIS inguinal hernia repair on regression analysis. Patients aged 65 and older were less likely to receive MIS repair than patients younger than 44 (OR 0.68, $p = 0.003$). Black patients were less likely to receive MIS than white patients (OR 0.75, $p = 0.045$). There were no differences on multivariate analysis in MIS utilization with respect to gender, obesity, and tobacco use.

In the hierarchical model, correcting for hospital-level differences explained 38% of the total variation in MIS utilization rate in patients. Larger hospital bed size was associated with increased utilization of MIS hernia repair. Compared to hospitals with fewer than 100 beds, hospitals with 200–499 beds (OR 3.80, $p = 0.009$) and ≥ 500 beds (OR 4.72, $p = 0.044$) were more likely to perform MIS repair. This relationship was not seen with hospitals sized 100–199 beds (OR 1.43, $p = 0.543$). Teaching hospitals had similar MIS utilization rates to community hospitals.

Discussion

This is the first population-based study in the U.S. to show variation in MIS utilization in inguinal hernia repair between surgeons, with the majority of MIS repairs performed by the minority of surgeons. Additionally, over half of surgeons performed no MIS repairs at all. Surgeon practice patterns across the state corresponded to regional disparity in MIS rates, resulting in almost a five-fold variation in MIS rate across regions even after controlling for age, comorbidities,

Table 1 Patient characteristics by MIS or open repair

Characteristics	Open *N* (%)	Lap *N* (%)	*p*-value
Cases, *n*	4406 (73.5)	1586 (26.5)	
Age			< 0.001*
≤ 44	885 (20.1)	407 (25.7)	
45–64	1918 (43.5)	748 (47.2)	
≥ 65	1603 (36.4)	431 (27.2)	
Gender			0.322
Male	3971 (90.1)	1443 (91.0)	
Female	435 (9.9)	143 (9.0)	
Race			0.014*
White	3778 (85.8)	1385 (87.3)	
Black	403 (9.2)	109 (6.9)	
Other	42 (1)	11 (0.7)	
Unknown	183 (4.2)	81 (5.1)	
Insurance type			< 0.001*
Medicare	486 (11)	181 (11.4)	
Medicaid	1384 (31.4)	353 (22.3)	
Private	65 (1.5)	39 (2.5)	
Other	2429 (55.1)	980 (61.8)	
Self-pay	4 (0.1)	0 (0)	
Uninsured	38 (0.9)	33 (2.1)	
Region			< 0.001*
Ann Arbor	830 (18.8)	310 (19.6)	
Detroit	1600 (36.3)	714 (45)	
Grand rapids	973 (22.1)	317 (20)	
Lansing	446 (10.1)	68 (4.3)	
Saginaw	375 (8.5)	43 (2.7)	
Traverse city	182 (4.1)	134 (8.5)	
Obesity			0.587
Obese	840 (19.1)	301 (19)	
Not obese	3562 (80.8)	1282 (80.8)	
Unknown	4 (0.1)	3 (0.2)	
Tobacco use	1063 (24.1)	406 (25.6)	0.242
Alcohol use	164 (3.7)	72 (4.5)	0.151
Functional status: not independent	31 (0.7)	11 (0.7)	0.821
ASA class: 3–4	1305 (29.6)	343 (21.6)	< 0.001*
Diabetes	427 (9.7)	140 (8.8)	0.313
Chronic obstructive pulmonary disease	272 (6.2)	51 (3.2)	< 0.001*
Hypertension	1863 (42.3)	550 (34.7)	< 0.001*
Congestive heart failure	10 (0.2)	2 (0.1)	0.441
Peripheral vascular disease	87 (2.0)	20 (1.3)	0.066
History of corticosteroid therapy	67 (1.5)	18 (1.1)	0.265
> 10% Body weight loss	15 (0.3)	2 (0.1)	0.269
Bleeding disorder	78 (1.8)	19 (1.2)	0.121
Wound left open	12 (0.3)	1 (0.1)	0.205
Bed size			< 0.001*
< 100	1217 (27.6)	280 (17.7)	
100–199	1026 (23.3)	336 (21.2)	
200–499	1720 (39)	766 (48.3)	
≥ 500	443 (10.1)	204 (12.9)	

Table 1 (continued)

Characteristics	Open *N* (%)	Lap *N* (%)	*p*-value
Teaching status			0.028*
Teaching hospital	148 (9.5)	181 (11.4)	
Not teaching hospital	3988 (90.5)	1405 (88.6)	

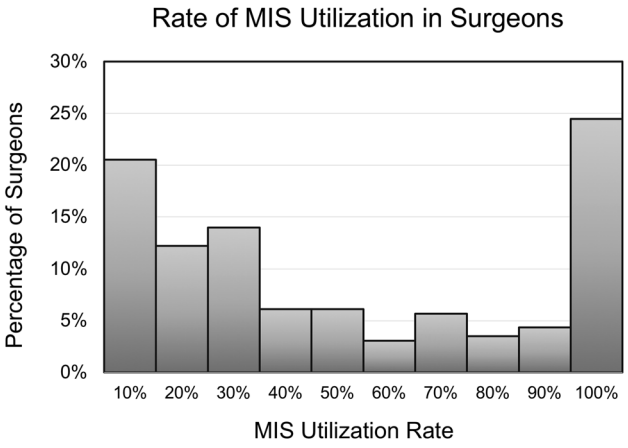

Fig. 1 Surgeon MIS utilization rate. MIS utilization rate in surgeons who performed any MIS (227 surgeons). The distribution of MIS utilization was bimodal, with 31% of surgeons using MIS in 75% or greater of their cases

and insurance. For example, a 60-year-old white male patient with hypertension and private insurance would have a 10% likelihood of receiving MIS repair if he sought his operation in northeast Michigan; that same patient would have a 48% likelihood of MIS repair in the northern Michigan/Upper Peninsula region. The high MIS rate in the northern region of Michigan was unexpected, as this area is more remote and rural than other areas of Michigan, with an average population of 1–25/mile^2 compared to > 5000/mile^2 in the Detroit area [20]. However, this finding may be explained by the relatively large proportion of high MIS-utilization surgeons in this region, indicating that regional variation in MIS rate may be driven by surgeon practice.

These findings suggest that a large portion of decision-making to offer MIS repair may depend on surgeon differences, rather than clinical appropriateness. The likelihood that a patient receives MIS repair may thus be pre-determined by the surgeon to whom they are referred. The predominant use of open repair may not be as important for a patient with unilateral hernia, but surgeons who primarily perform open repair may default to this technique even for patients with bilateral or recurrent hernias. Accordingly, we found that over half of bilateral and recurrent inguinal hernias were repaired with open technique, indicating guideline-discordant care in the majority of these cases. Given the benefit of MIS repair in certain clinical scenarios, between-surgeon variation in MIS utilization may differentially affect

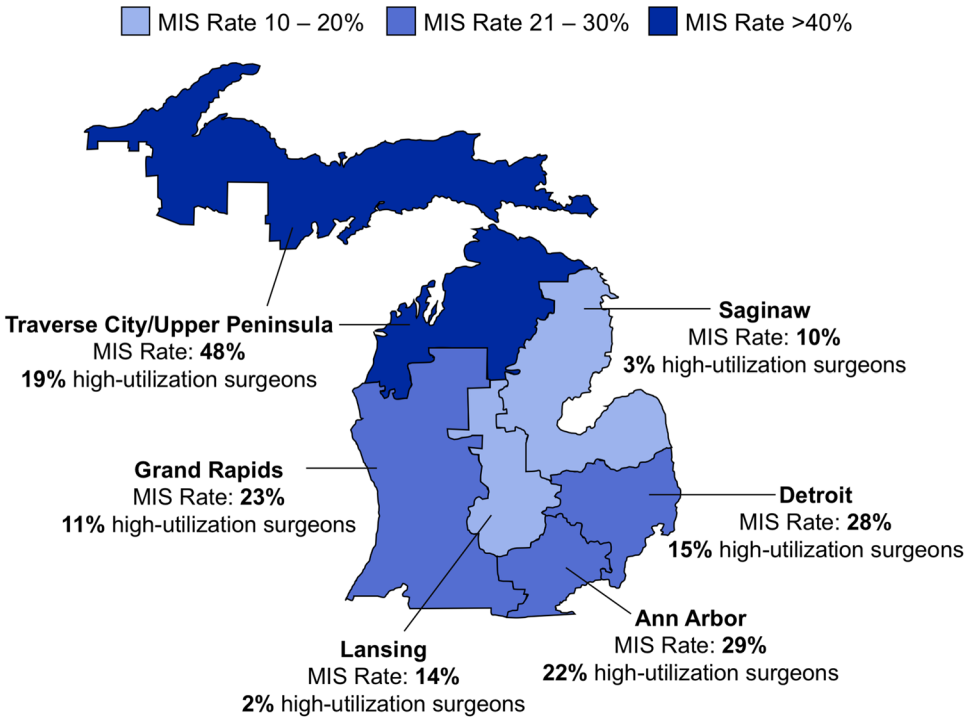

Fig. 2 Geographic variation in MIS repair rate and surgeon utilization. Geographic variation in MIS inguinal hernia repair rate and distribution of high-utilization surgeons. The region with the highest utilization was the Traverse City/Upper Peninsula region, which also had a relatively high proportion of surgeons who used MIS in 75% or greater of their cases

Table 2 Multivariate hierarchical regression model for patient and hospital characteristics associated with receiving MIS hernia repair

	Odds ratio of receiving MIS repair	*p*-value	95% Confidence interval	
Age (ref group: ≤ 44)				
45–64	0.874	0.132	0.734	1.041
≥ 65	0.676	0.003*	0.523	0.872
Race (ref group: White)				
Black	0.747	0.045	0.562	0.994
Other	0.605	0.178	0.291	1.257
Unknown	1.076	0.650	0.783	1.479
Insurance (ref group: Private)				
Medicaid	0.895	0.339	0.713	1.124
Medicare	0.785	0.032*	0.629	0.979
Other	1.567	0.074	0.958	2.562
Self-pay	1.000			
Uninsured	1.035	0.920	0.532	2.012
ASA Class 3–4	0.792	0.013*	0.659	0.951
COPD	0.570	0.001*	0.403	0.806
Bed size (ref group: less than 100)				
100–199	1.415	0.551	0.452	4.430
200–499	3.840	0.009*	1.389	10.614
≥ 500	4.722	0.044*	1.040	21.446

*$p < 0.05$

patient outcomes after inguinal hernia repair and represents a barrier in access to MIS repair.

We also found patient characteristics that were independently associated with differences in MIS utilization. Consistent with other population-based studies, patients with higher comorbid burden, specifically COPD or higher ASA class, were less likely to receive MIS repair. These findings likely reflect potential advantages of open approach in these patients, given the increased risk of complication with laparoscopy and general anesthesia. More troubling were the differences in MIS utilization for black and older patients, even after accounting for patient and hospital characteristics. Holding all other factors equal, a black or older patient with the same comorbidities and at the same hospital was less likely to receive MIS repair compared to white or younger patients.

The differences in MIS utilization by race and age may stem from multiple causes, many of which are not explained by our data source, including socioeconomic status, provider bias, or patient preference. Access to hospitals and surgeons that perform MIS repair may have mediated these differences, but we adjusted for these effects by controlling for region and hospital. The effect of older age was independent of the decreased utilization for Medicare patients, meaning that this disparity is compounded, rather than mediated, by insurance status. Selection by clinical indication may also have contributed to our findings, as older and black patients may present with more advanced hernias less amenable to MIS repair [21–23]. Additionally, older patients may have had unmeasured comorbidities, especially as we had no measure of overall frailty in our dataset. However, octogenarians have been shown to have equivalent clinical outcomes after MIS repair compared to younger patients, and there is no evidence that race has an independent effect on hernia repair outcomes [24–26].

There are several limitations of this study to consider, the most important one being the inherent bias of observational studies. While this study finds associations between patient and provider factors and MIS utilization, we cannot infer causality given unobserved confounders and selection bias, such as possible clustering of sicker patients at particular hospitals. However, we adjusted for comorbid conditions, surgeon, and hospital site in our regression models to isolate independent effects of each attribute on the likelihood of receiving MIS repair. Additionally, generalizability of these results may be limited by the fact that these are data from hospitals voluntarily contributing clinical data to the MSQC. These hospitals, however, include community as well as academic hospitals that range in bed size and volume. Additionally, as participation in the quality improvement collaborative is supported by outside funding, our data are more inclusive than other clinical registries where data contribution may be costly. Lastly, our dataset did not include data on hernia attributes, such as defect size or skin complications; for recurrent hernias, we did not have information about the approach of the previous repair. If some of these recurrent hernia repairs were initially performed using MIS, an open repair of the recurrence would be recommended, and our findings may underestimate guideline concordance in these cases.

Identifying the barriers and facilitators to surgeon adoption of MIS repair is imperative in designing interventions to increase MIS utilization, particularly for the patients with bilateral or recurrent hernias receiving inappropriate care. One possible barrier is financial—laparoscopic repair takes capital to establish in a practice given higher equipment costs and is costlier overall, but yields fewer work Relative Value Units (wRVUs) compared to open repair (6.36 wRVUs for laparoscopic repair of initial inguinal hernia, versus 7.96 wRVUs for open, initial, reducible inguinal hernia) [10, 27, 28]. Surgeons' lack of experience and the long learning curve of MIS repair may be other important primary barriers to adoption, leading to the between-surgeon variation in our findings. The 2004 randomized controlled trial performed through Veteran's Affairs hospitals suggested that 250 laparoscopic repairs were needed before surgeons attained proficiency and equivalent outcomes with MIS techniques [29]. Targeted training interventions involving simulation or expert coaching, especially for busy surgeons

already in practice, may increase adoption and have shown success in laparoscopic ventral hernia repair, as well as in inguinal hernia on a smaller scale [30, 31].

In contrast, recommending training and education for all surgeons not currently performing MIS is not feasible and is unlikely to result in the desired practice change. For patients with bilateral or recurrent inguinal hernias, healthcare delivery system reform may be the preferred intervention to improve access and increase guideline-concordant practice. Selective referral or regionalization of care in these cases may ensure better access to MIS. The collaborative statewide community of the MSQC provides an infrastructure for this implementation. We plan to address this practice gap now by sharing our findings and existing best practices within the MSQC, setting a goal of increasing MIS rates in bilateral and recurrent hernias to 75% by 2020, discussing surgeons' barriers and facilitators to MIS adoption at face-to-face meetings, and setting referral pathways in place.

Conclusions

Using robust, population-based data, this study revealed that surgeon practice is highly influential in the likelihood of receiving MIS inguinal hernia repair, resulting in wide variation in MIS utilization across geographic region. Interventions to improve guideline adherence are difficult if the barriers to and facilitators of MIS utilization are unclear, and deeper investigation into the drivers of provider decision-making in inguinal hernia repair is needed. Whether through novel training interventions or by establishing regional referral networks to improve access to MIS repair, improvement in MIS delivery and access is needed to reduce disparity and promote evidence-based practice.

Funding Dr. Vu is funded by the National Institutes of Health T32 Obesity Surgery Scientist Training Program: 1 T32 DK 108740-1.

Compliance with ethical standards

Disclosures Dr. Telem receives consulting fees for Medtronic. Dr. Vu, Ms. Gunaseelan, Dr. Krapohl, Dr. Englesbe, Dr. Campbell, and Dr. Dimick have no conflict of interest or financial ties to disclose.

References

1. Smink DS, Paquette IM, Finlayson SR (2009) Utilization of laparoscopic and open inguinal hernia repair: a population-based analysis. J Laparoendosc Adv Surg Tech A 19(6):745–748
2. Zendejas B, Ramirez T, Jones T et al (2012) Trends in the utilization of inguinal hernia repair techniques: a population-based study. Am J Surg 203(3):313–317
3. Trevisonno M, Kaneva P, Watanabe Y et al (2015) Current practices of laparoscopic inguinal hernia repair: a population-based analysis. Hernia 19(5):725–733
4. Ielpo B, Duran H, Diaz E et al (2017) A prospective randomized study comparing laparoscopic transabdominal preperitoneal (TAPP) versus Lichtenstein repair for bilateral inguinal hernias. Am J Surg 216:78–83
5. Bignell M, Partridge G, Mahon D, Rhodes M (2012) Prospective randomized trial of laparoscopic (transabdominal preperitoneal-TAPP) versus open (mesh) repair for bilateral and recurrent inguinal hernia: incidence of chronic groin pain and impact on quality of life: results of 10 year follow-up. Hernia 16(6):635–640
6. Bowling K, El-Badawy S, Massri E et al (2017) Laparoscopic and open inguinal hernia repair: patient reported outcomes in the elderly from a single centre—a prospective cohort study. Ann Med Surg 22:12–15
7. Eker HH, Langeveld HR, Klitsie PJ et al (2012) Randomized clinical trial of total extraperitoneal inguinal hernioplasty vs lichtenstein repair: a long-term follow-up study. Arch Surg 147(3):256–260
8. McCormack K, Scott NW, Go PM, Ross S, Grant AM (2003) Laparoscopic techniques versus open techniques for inguinal hernia repair. Cochrane Database Syst Rev 2003(1):Cd001785
9. Abbas AE, Abd Ellatif ME, Noaman N et al (2012) Patient-perspective quality of life after laparoscopic and open hernia repair: a controlled randomized trial. Surg Endosc 26(9):2465–2470
10. Wang WJ, Chen JZ, Fang Q, Li JF, Jin PF, Li ZT (2013) Comparison of the effects of laparoscopic hernia repair and Lichtenstein tension-free hernia repair. J Laparoendosc Adv Surg Tech A 23(4):301–305
11. Westin L, Wollert S, Ljungdahl M, Sandblom G, Gunnarsson U, Dahlstrand U (2016) Less pain 1 year after total extra-peritoneal repair compared with lichtenstein using local anesthesia: data from a randomized controlled clinical trial. Ann Surg 263(2):240–243
12. Simons MP, Aufenacker T, Bay-Nielsen M et al (2009) European Hernia Society guidelines on the treatment of inguinal hernia in adult patients. Hernia 13(4):343–403
13. Bittner R, Arregui ME, Bisgaard T et al (2011) Guidelines for laparoscopic (TAPP) and endoscopic (TEP) treatment of inguinal Hernia [International Endohernia Society (IEHS)]. Surg Endosc 25(9):2773
14. Choudhary RK, Hassn AMF (2003) NICE guidance on laparoscopic surgery for inguinal hernias: guidelines are less clinical excellence than hindrance. Br Med J 326(7399):1144–1144
15. Davis CH, Shirkey BA, Moore LW et al (2018) Trends in laparoscopic colorectal surgery over time from 2005 to 2014 using the NSQIP database. J Surg Res 223:16–21
16. Tsui C, Klein R, Garabrant M (2013) Minimally invasive surgery: national trends in adoption and future directions for hospital strategy. Surg Endosc 27(7):2253–2257
17. Hendren S, Fritze D, Banerjee M et al (2013) Antibiotic choice is independently associated with risk of surgical site infection after colectomy: a population-based cohort study. Ann Surg 257(3):469–475
18. Waits SA, Fritze D, Banerjee M et al (2014) Developing an argument for bundled interventions to reduce surgical site infection in colorectal surgery. Surgery 155(4):602–606
19. The Center for the Evaluative Clinical Sciences DMS (1996) The Dartmouth atlas of health care. American Hospital Publishing, Chicago
20. 2010 Census Summary File—Michigan (2010) http://www.census.gov/2010census/data/. Accessed 12 Feb 2018
21. Hernández-Irizarry R, Zendejas B, Ramirez T et al (2012) Trends in emergent inguinal hernia surgery in Olmsted County, MN: a population-based study. Hernia 16(4):397–403

22. Beadles CA, Meagher AD, Charles AG (2015) Trends in emergent hernia repair in the united states. JAMA Surg 150(3):194–200
23. Mehta A, Hutfless S, Blair AB et al (2017) Emergency department utilization and predictors of mortality for inpatient inguinal hernia repairs. J Surg Res 212:270–277
24. Hope WW, Bools L, Menon A, Scott CM 3rd, Adams A, Hooks WB (2013) Comparing laparoscopic and open inguinal hernia repair in octogenarians. Hernia 17(6):719–722
25. Vigneswaran Y, Gitelis M, Lapin B et al (2015) Elderly and octogenarian cohort: comparable outcomes with nonelderly cohort after open or laparoscopic inguinal hernia repairs. Surgery 158(4):1137–1144
26. Dallas KB, Froylich D, Choi JJ et al (2013) Laparoscopic versus open inguinal hernia repair in octogenarians: a follow-up study. Geriatr Gerontol Int 13(2):329–333
27. McCormack K, Wake BL, Fraser C, Vale L, Perez J, Grant A (2005) Transabdominal pre-peritoneal (TAPP) versus totally extraperitoneal (TEP) laparoscopic techniques for inguinal hernia repair: a systematic review. Hernia 9(2):109–114
28. Physician Fee Schedule Search (2018) https://www.cms.gov/apps/physician-fee-schedule/overview.aspx. Accessed 14 April 2018
29. Neumayer L, Giobbie-Hurder A, Jonasson O et al (2004) Open mesh versus laparoscopic mesh repair of inguinal hernia. New Engl J Med 350(18):1819–1827
30. Zerey M, Kercher KW, Sing RF et al (2007) Does a one-day course influence surgeon adoption of laparoscopic ventral herniorrhaphy? J Surg Res 138(2):205–208
31. Greenberg JA, Jolles S, Sullivan S et al (2017) A structured, extended training program to facilitate adoption of new techniques for practicing surgeons. Surg Endosc 32:217–224