Predictors of Minimally Invasive Myomectomy in the National Inpatient Sample Database, 2010–2014

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ABSTRACT

Background and Objectives: This study aims to characterize the utilization of minimally invasive myomectomy in the United States and to identify the patient and hospital factors associated with surgical approach to myomectomy.

Methods: This is a cross-sectional study using the National Inpatient Sample database. We extracted women aged 18–50 years who underwent open and minimally invasive (laparoscopic and robotic) myomectomy (MIM) from January 1, 2010–December 31, 2014. Descriptive statistics were obtained for patient and hospital characteristics. We then performed multivariable logistic regression to examine the association of patient (age, race, insurance status, median household income) and hospital (bed size, teaching status, for-profit status, census region, cases volume) characteristics with the likelihood of undergoing MIM.

Results: Of 114,850 myomectomy cases, 8,330 (7%) underwent MIM and 106,520 (93%) were open. Over time, the proportion of MIM remained very low and slightly decreased from 8.2% in 2010 to 6.1% in 2014 (p-for-trend: 0.001). Most hospitals performed few MIM per year, with 50% performing five or less, and 25% performing three or fewer per year. African American, Hispanic, and women of other races were less likely to undergo MIM compared to Caucasian women (adjusted odds ration [OR] 0.57, 95% confidence interval [CI] 0.50–0.64; 0.71, 95% CI 0.60–0.83; 0.62, 95% CI 0.52–0.74, respectively). Women in the West (adjusted odds ratio (aOR) 1.23, 95% CI 1.04–1.46) and Midwest (aOR 1.27, 95% CI 1.07–1.52) had higher odds of undergoing MIM.

Conclusion: MIM appears to be an underutilized modality, accounting for less than 10% of myomectomies. This underutilization disproportionately affects minority women.

Key Words: Fibroids, Myomectomy, Minimally invasive, Laparoscopic, Robotic.

INTRODUCTION

Uterine fibroids are the most common benign tumor of the uterus with a lifetime incidence of up to 70%–80%. While advances in uterine preserving procedures and medical management of myomas have gained momentum, many symptomatic women ultimately require surgical management. Myomectomy remains the gold standard for surgical management for women desiring future fertility.

With the advent of minimally invasive surgery (MIS), laparoscopic and robotic-assisted techniques are preferred over the open approach due to less blood loss, postoperative pain, shorter hospital stay, and decreased morbidity, even in high-risk conditions such as obesity. Minimally invasive myomectomy (MIM) is feasible even in cases with large fibroids. Although the use of MIS hysterectomy, has increased, there is still little data regarding overall utilization of MIM. Most existing data come from studies exploring changes in practice after the FDA power morcellation recommendation. The limited literature suggests that MIM remains underutilized, despite proven advantages.

African American and other non-Caucasian women appear to be less likely to undergo MIS hysterectomy, but potential disparities have not been studied in myomectomy. Given the significantly higher prevalence of myomas in...
non-Caucasian women, there is a potential for disparities in this population. Only one study has examined racial disparities in myomectomy where minority women were more likely to undergo open myomectomy than Caucasian women. African American women had 50% increased odds of morbidity after open myomectomy including twice as likely to be readmitted, return to the operating room, receive a transfusion, and to experience thromboembolic phenomena, even after controlling for the myoma burden. However, this study did not include other patient and hospital variables. Hospital variables have been shown to impact the surgical approach for hysterectomy.

The objectives of this study are to characterize the utilization of MIM and to examine the association of patient and hospital characteristics with surgical approach to myomectomy.

**MATERIAL AND METHODS**

This study was reviewed by the Johns Hopkins School of Medicine Institutional Review Board and determined to be exempt as data was de-identified and publicly available.

We used hospital reported data from the 2010–2014 National Inpatient Sample (NIS) database. The NIS is the largest publicly available, all-payer database of hospitalizations in the United States, including over 7 million hospitalizations from more than 4,000 hospitals annually. It includes surgical procedures, including myomectomy, in which women were admitted or observed one or more nights post-procedure. All data was reweighted to account for the redesign of the NIS in 2012, and prior studies have not found significant differences with the change in sample design for surgical outcomes.

Women aged 18 to 50 years who underwent laparoscopic, robotic, and open myomectomy for fibroids were identified and included. We included women in whom fibroids and myomectomy were listed as one of the top 10 diagnoses or conditions during their hospitalization (International Classification of Disease [ICD]-9 for fibroids 218, 2180.0, 2180.1, 2180.2, 2180.9). We did not limit fibroids to the primary diagnosis to allow for other presenting complaints that are secondary to fibroids, such as abnormal uterine bleeding, symptomatic anemia, or pelvic pain. To minimize the inclusion of patients miscoded as having myomectomy, we excluded patients who did not have a diagnosis of fibroids among their first 10 diagnosis codes (n = 18,900 women); the most frequent diagnoses for these women were renal cancer (which has a similar ICD-9 code to fibroids).

Our primary outcome was undergoing MIM versus open myomectomy. We identified myomectomy approach using ICD-9 codes. Myomectomy approaches were categorized as open (ICD-9 68.19 or 68.29, without 54.21) or minimally invasive (ICD-9 68.19 or 68.29 with 54.21, 170.4, 17.41, 17.42, or 17.44); cases that were converted to open would be classified as open. Women who had a code for robotic-assisted procedure (ICD-9 170.4, 17.41, 17.42, or 17.44) were classified as having undergone robotic myomectomy. Given the small number of robotic myomectomies identified, we pooled robotic and laparoscopic myomectomies together for analysis.

In this study, we performed descriptive statistics for characterization and used multivariable logistic regression models to examine the association of patient (age, race, insurance status, median household income) and hospital (bed size, teaching status, for-profit status, Census region) factors with the likelihood of undergoing MIM (laparoscopic and robotic only) compared to open myomectomy. We added a hospital variable to account for hospital-level clustering.

For patient factors, age was stratified into four categories (ages 18–20, 21–30, 31–40, 41–50 years). Insurance status was categorized as private, public, and uninsured. Uninsured and publicly-insured were grouped together in final analysis, given the small number of uninsured women (less than 2,500 women per year). Median household income was defined as the median income in the patient’s zip code and was divided into quartiles by year (2014 quartiles: less than $40,00, $40,000–$50,999, $51,000–$65,999, $66,000 or more). Although the NIS lacks patient-level income data, the zip code-based variables highly correlate with actual patient income.

We used NIS definitions for hospital factors. A hospital was considered a teaching hospital if it was a member of the Council of Teaching hospitals, had a residency program, or had a full-time resident to hospital bed equivalent ratio of 0.25. For-profit status was classified using the American Hospital Association Annual Survey of Hospitals; we considered both government-owned and private, not-for-profit hospitals as nonprofit. Hospital census region was categorized as Northeast, South, Midwest, and West. Large hospital bed size was defined using the NIS definition of 45 or more beds with variance in size categories by Census region and teaching status.

We defined hospital myomectomy volume as the number of cases who underwent myomectomy per year averaged over the five years of study. We divided myomectomy volume into low, medium, and high based on approximate tertiles. Low-volume was defined as 0–6 myomectomies per year, medium-volume as 7–15 myomectomies per

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**Predictors of Minimally Invasive Myomectomy in the National Inpatient Sample Database, 2010–2014, Frost AS et al.**

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October–December 2021 Volume 25 Issue 4 e2021.00065 2 JSLS www.SLS.org
year, and high-volume as 16 or more myomectomies per year. We excluded women missing any of the above patient or hospital characteristics from our analyses (n ~ 10,000 cases).

**Statistical Analysis**

For descriptive statistics, we examined the frequency of patient and hospital characteristics and compared between MIM and open myomectomy using $\chi^2$ statistics. We examined trends in MIM over time using both univariable and multivariable logistic regression models, adjusted for above patient and hospital characteristics. We then used a logistic regression model to examine the association of patients and hospital characteristics on the likelihood of undergoing MIM in univariable and then multivariable analyses. We used NIS weighting by hospital discharges to obtain population-level estimates in all analyses. Two-sided $p$-values < 0.05 were considered significant. Analyses were performed using Stata version 11 (StataCorp, Texas).

We conducted sensitivity analyses first by examining the association of patients and hospital characteristics on the likelihood of undergoing MIM in univariable and then multivariable analyses. We used NIS weighting by hospital discharges to obtain population-level estimates in all analyses. Two-sided $p$-values < 0.05 were considered significant. Analyses were performed using Stata version 11 (StataCorp, Texas).

**RESULTS**

A total of 114,850 women underwent inpatient myomectomy for fibroids from January 1, 2010 –December 31, 2014. Of these, 106,520 (92.8%, 95% CI 92.4–93.1) underwent open myomectomy and 8,330 (7.2%, 95% CI 6.9–7.6) underwent MIM. During the study time frame, the proportion of MIM remained low and decreased from 59.8% (95% CI 57.5–62.8) in 2010 to 6.1% (95% CI 5.4–6.8) in 2014 ($p$-for-trend < 0.001).

There were statistically significant differences in baseline characteristics between women undergoing open myomectomy and MIM among age, race, hospital characteristics, region, and hospital volume (Table 1). Among all women undergoing myomectomy regardless of approach, the majority were between the ages of 31–40 years (55.9%, 95% CI 55.2–56.5). When looking only at MIM, the majority were between 41–50 years (57.5%, 95% CI 55.1–59.8). African American women underwent most myomectomies (44.5%, 95% CI 43.9–45.1); however, they only accounted for one-third of MIM (33.8%, 95% CI 31.5–36.0). Caucasian women underwent 29.6% (95% CI 29.0–30.2) of myomectomies but accounted for 41.8% of MIM (95% CI 39.5–44.2). Geographically, most myomectomies were performed in the South (41.8%, 95% CI 41.1–42.4) and the minority in the Midwest (12.4%, 95% CI 12.0–12.8). Of MIM, 38.6% (95% CI 36.3–41.0) were performed in hospitals performing 0–6 myomectomies per year, 30.6% (95% CI 28.4–32.8) in hospitals performing 7–15 myomectomies per year, and 30.8% (95% CI 28.6–33.0) in hospitals performing 16 or more myomectomies per year.

Mean annual hospital volume for all myomectomies was 13 cases (95% CI 13–14). Most hospitals perform very few MIM per year with 50% performing five or fewer, and 25% performing three or fewer. Average length of stay for all approaches was 2.62 days (95% CI 2.59–2.65). Length of stay was slightly shorter for MIM versus open myomectomy (2.48 days; 95% CI 2.38–2.57 and 2.63 days; 95% CI 2.60–2.66, respectively, $P < .001$). A higher proportion of women who underwent MIM were hospitalized 24 hours or fewer than women undergoing open myomectomy [27.3% (95% CI 25.1–29.4) vs. 16.6% (95% CI 16.2–17.1), $P < .001$].

Among all women undergoing myomectomy during the study period (n = 114,850), African American women had lower odds of undergoing MIM (OR 0.57, 95% CI 0.50–0.64) compared to Caucasian women. Hispanic women (OR 0.71, 95% CI 0.60–0.83) and women of other races (OR 0.62, 95% CI 0.52–0.74) also had lower odds of undergoing MIM compared to Caucasian women. Women in the West (OR 1.23, 95% CI 1.04–1.46) and Midwest (OR 1.27, 95% CI 1.07–1.52) had higher odds of undergoing MIM. Women in higher income brackets (third quartile OR 0.85, 95% CI 0.73–0.98; highest quartile OR 0.75, 95% CI 0.65–0.87), and those having surgery at teaching hospitals (OR 80, 95% CI 0.72–0.91) had lower odds of undergoing MIM. Hospitals with the highest volume of myomectomies had lower odds of performing MIM (OR 0.84 95% CI 0.71–0.99) compared to low-volume hospitals (0–6 per year) (Table 2).

Subgroup analyses showed that, among African American women only, there were lower odds of MIM in high-income brackets (third quartile OR 0.73 95% CI 0.58–0.92; highest quartile 0.69 95% CI 0.54–0.88) without a statistically significant difference among other patient or hospital characteristics. Among Caucasian women only, there were lower odds of undergoing MIM with private insurance (OR 0.76 95% CI 0.61–0.95), in the highest income brackets.
## Table 1.
Baseline Characteristics of Women Undergoing Myomectomies, 2010–2014

|                      | All Cases% (95% CI) | Minimally Invasive Surgery Cases% (95% CI) | Open Cases% (95% CI) | p-Value |
|----------------------|---------------------|----------------------------------------|---------------------|---------|
| **Year**             |                     |                                        |                     |         |
| 2010                 | 21.3 (20.8–21.8)    | 24.2 (22.1–26.2)                      | 21.1 (20.5–21.6)    | < 0.001 |
| 2011                 | 20.4 (19.9–20.9)    | 22.8 (20.8–24.8)                      | 20.2 (19.7–20.7)    |         |
| 2012                 | 20.0 (19.5–20.5)    | 18.4 (16.5–20.2)                      | 20.1 (19.6–20.6)    |         |
| 2013                 | 18.7 (18.2–19.2)    | 18.2 (16.3–20.0)                      | 18.8 (18.2–19.3)    |         |
| 2014                 | 19.6 (19.1–20.1)    | 16.5 (14.7–18.2)                      | 19.9 (19.3–20.4)    |         |
| **Patient Characteristics** |                   |                                        |                     |         |
| **Age**              |                     |                                        |                     |         |
| 18–20 years          | 0.3 (0.2–0.3)       | 0.2 (0.0–0.5)                         | 0.3 (0.2–0.3)       | 0.81    |
| 21–30 years          | 14.9 (14.5–15.4)    | 8.8 (7.5–10.2)                        | 15.4 (14.9–15.9)    | < 0.001 |
| 31–40 years          | 55.9 (55.2–56.5)    | 33.5 (31.2–35.7)                      | 57.6 (56.9–58.3)    | < 0.001 |
| 41–50 years          | 29.0 (28.4–29.5)    | 57.5 (55.1–59.8)                      | 26.8 (26.2–27.3)    | < 0.001 |
| **Race**             |                     |                                        |                     |         |
| Caucasian            | 29.6 (29.0–30.2)    | 41.8 (39.5–44.2)                      | 28.7 (28.1–29.3)    | < 0.001 |
| African American     | 44.5 (43.9–45.1)    | 33.8 (31.5–36.0)                      | 45.3 (44.6–45.9)    | < 0.001 |
| Hispanic             | 13.5 (13.1–14.0)    | 13.6 (12.0–15.3)                      | 13.5 (13.1–14.0)    | 0.92    |
| Other race(s)        | 12.3 (11.9–12.8)    | 10.8 (9.3–12.2)                       | 12.5 (12.0–12.9)    | 0.02    |
| **Insurance type**   |                     |                                        |                     |         |
| Private              | 75.3 (74.8–75.9)    | 74.8 (72.7–76.9)                      | 75.4 (74.8–76.0)    | 0.62    |
| Public               | 18.8 (18.3–19.3)    | 19.1 (17.2–20.9)                      | 18.7 (18.2–19.2)    | 0.52    |
| Uninsured            | 5.9 (5.6–6.2)       | 6.1 (5.0–7.2)                         | 5.9 (5.6–6.2)       | 0.52    |
| **Household income** |                     |                                        |                     |         |
| Lowest quartile      | 24.1 (23.6–24.7)    | 24.7 (22.7–26.8)                      | 24.0 (23.5–24.6)    | 0.29    |
| 2nd quartile         | 21.1 (20.6–21.6)    | 22.2 (20.2–24.2)                      | 21.0 (20.4–21.5)    | 0.14    |
| 3rd quartile         | 25.8 (25.3–26.4)    | 25.5 (23.4–27.5)                      | 25.9 (25.3–26.5)    | 0.47    |
| Highest quartile     | 29.0 (28.4–29.6)    | 27.6 (25.5–29.7)                      | 29.1 (28.5–29.7)    | 0.10    |
| **Hospital Characteristics** |                 |                                        |                     |         |
| Large hospital       | 60.7 (60.1–61.3)    | 60.2 (57.8–62.5)                      | 39.2 (38.6–39.9)    | 0.24    |
| Teaching hospital    | 65.3 (64.7–65.9)    | 58.0 (55.6–60.4)                      | 65.9 (65.3–66.5)    | 0.001   |
| For-profit hospital  | 13.7 (13.2–14.1)    | 13.7 (12.0–15.3)                      | 13.6 (13.2–14.1)    | 0.82    |
| **Region**           |                     |                                        |                     |         |
| Northeast            | 25.1 (24.6–25.7)    | 22.2 (20.2–24.2)                      | 25.3 (24.7–25.9)    | 0.04    |
| South                | 41.8 (41.1–42.4)    | 38.1 (35.8–40.4)                      | 42.0 (41.3–42.6)    | 0.02    |
| Midwest              | 12.4 (12.0–12.8)    | 14.4 (12.7–16.1)                      | 12.2 (11.8–12.7)    | 0.001   |
| West                 | 20.7 (20.2–21.2)    | 25.3 (23.2–27.4)                      | 25.3 (23.2–27.4)    | 0.01    |
| **Hospital cases per year** |             |                                        |                     |         |
| 0–6                  | 34.9 (34.3–35.5)    | 38.6 (36.3–41.0)                      | 34.7 (34.0–35.3)    | 0.001   |
| 7–15                 | 31.0 (30.4–31.6)    | 30.6 (28.4–32.8)                      | 31.1 (30.5–31.7)    | 0.38    |
| 16+                  | 34.0 (33.4–34.7)    | 30.8 (28.6–33.0)                      | 34.2 (33.6–34.9)    | 0.02    |

CI, confidence interval.
Unweighted n is 23,628 myomectomies in 6,011 hospitals.
Proportions are within each group.
2014 income quartiles: less than $40,000, $40,000–$50,999, $51,000–$65,999, $66,000 or more.
| Year       | Univariate Analysis | Multivariable Analysis |
|------------|---------------------|------------------------|
|            | Odds Ratio (95% CI) | Odds Ratio (95% CI)    |
|            | p-Value             | p-Value                |
| 2010       | 1.20 (1.06–1.34)    | 0.90 (0.86–0.95)       |
| 2011       | 1.17 (1.04–1.31)    | 1.22 (1.09–1.35)       |
| 2012       | 0.89 (0.79–1.02)    | 0.73 (0.65–0.82)       |
| 2013       | 0.96 (0.85–1.10)    | 0.85 (0.77–0.93)       |
| 2014       | 0.79 (0.69–0.91)    | 0.59 (0.50–0.70)       |

| Patient Characteristics | Univariate Analysis | Multivariable Analysis |
|-------------------------|---------------------|------------------------|
|                         | Odds Ratio (95% CI) | Odds Ratio (95% CI)    |
|                         | p-Value             | p-Value                |
| Age                     |                     |                        |
| 18–20 years             | 0.91 (0.33–2.52)    | Reference              |
| 21–30 years             | 0.53 (0.45–0.63)    | 0.57 (0.50–0.64)       |
| 31–40 years             | 0.37 (0.33–0.41)    | 0.74 (0.62–0.87)       |
| 41–50 years             | 3.70 (3.35–4.10)    | 2.66 (0.94–7.48)       |
| Race                    |                     |                        |
| Caucasian               | 1.79 (1.62–1.98)    | Reference              |
| African American        | 0.62 (0.55–0.68)    | 0.71 (0.61–0.83)       |
| Hispanic                | (0.87–1.17)         | 0.62 (0.52–0.74)       |
| Other race(s)           | 0.85 (0.72–0.99)    |                        |
| Insurance type          |                     |                        |
| Public and Uninsured    | 1.03 (0.92–1.15)    | 0.92 (0.82–1.05)       |
| Private                 | 0.97 (0.87–1.09)    |                        |
| Household income        |                     |                        |
| Lowest quartile         | 1.04 (0.92–1.16)    | 0.94 (0.84–1.05)       |
| 2nd quartile            | 1.08 (0.95–1.21)    | 0.80 (0.72–0.91)       |
| 3rd quartile            | 0.98 (0.87–1.10)    | 0.75 (0.65–0.87)       |
| Highest quartile        | 0.93 (0.83–1.04)    |                        |
| Hospital Characteristics|                     |                        |
| Large hospital          | 0.98 (0.89–1.07)    | 0.94 (0.84–1.05)       |
| Teaching hospital       | 0.73 (0.67–0.80)    | 0.80 (0.72–0.91)       |
| For-profit hospital     | 1.00 (0.88–1.15)    | 0.90 (0.77–1.05)       |
| Region                  |                     |                        |
| Northeast               | 0.84 (0.75–0.95)    | Reference              |
| South                   | 0.85 (0.77–0.94)    | 1.07 (0.92–1.24)       |
| Midwest                 | 1.20 (1.05–1.39)    | 1.27 (1.07–1.52)       |
| West                    | 1.33 (1.18–1.49)    | 1.23 (1.04–1.46)       |
| Hospital cases per year |                     |                        |
| 0–6                     | 1.19 (1.07–1.32)    | 0.84 (0.71–0.99)       |
| 7–15                    | 0.98 (0.88–1.09)    |                          |
| 16+                     | 0.85 (0.77–0.95)    |                          |

CI, confidence interval.
Unweighted n is 23,628 myomectomies in 6,011 hospitals.
Multivariable analysis weighted and adjusted for all patient and hospital characteristics.
Large hospital size was defined as 45 or more beds with variance in size categories by Census region and teaching status.
2014 income quartiles: less than $40,000, $40,000–$50,000, $50,000–$65,000, $66,000 or more.
| Association of Minimally Invasive Myomectomy with Patient, Hospital, and Gynecologic Characteristics by Race (n = 114,850 Myomectomies) |
|---|---|---|---|---|---|---|
| | African American Women | | | Caucasian Women | | |
| | Odds Ratio (95% CI) | p-value | | Odds Ratio (95% CI) | p-value |
| Year | | | | | |
| 2010 | 0.89 (0.82–0.96) | 0.003 | | 0.91 (0.84–0.98) | 0.013 |
| 2011 | | | | | |
| 2012 | | | | | |
| 2013 | | | | | |
| 2014 | | | | | |
| Patient Characteristics | | | | | |
| Age | | | | | |
| 18–20 years | Reference | | | Reference | |
| 21–30 years | 0.40 (0.12–1.37) | 0.15 | | 0.78 (0.69–0.89) | 0.82 |
| 31–40 years | 0.37 (0.11–1.26) | 0.11 | | 0.97 (0.86–1.10) | 0.97 |
| 41–50 years | 1.07 (0.32–3.60) | 0.92 | | 4.81 (0.57–40.27) | 0.15 |
| Insurance type | | | | | |
| Public and Uninsured | Reference | | | Reference | |
| Private | 0.91 (0.75–1.10) | 0.33 | | 0.76 (0.61–0.95) | 0.02 |
| Household income | | | | | |
| Lowest quartile | Reference | | | Reference | |
| 2nd quartile | 0.79 (0.63–1.01) | 0.06 | | 0.98 (0.76–1.28) | 0.90 |
| 3rd quartile | 0.73 (0.58–0.92) | 0.008 | | 0.87 (0.67–1.12) | 0.28 |
| Highest quartile | 0.69 (0.54–0.88) | 0.003 | | 0.76 (0.59–0.98) | 0.04 |
| Hospital Characteristics | | | | | |
| Large hospital | 0.90 (0.75–1.09) | 0.29 | | 0.90 (0.75–1.07) | 0.24 |
| Teaching hospital | 0.82 (0.67–1.02) | 0.07 | | 0.74 (0.62–0.89) | 0.002 |
| For-profit hospital | 0.96 (0.73–1.26) | 0.79 | | 1.04 (0.82–1.34) | 0.73 |
| Region | | | | | |
| Northeast | Reference | | | Reference | |
| South | 1.07 (0.84–1.36) | 0.59 | | 1.01 (0.79–1.29) | 0.96 |
| Midwest | 1.33 (0.99–1.78) | 0.06 | | 1.27 (0.98–1.65) | 0.07 |
| West | 1.35 (0.95–1.91) | 0.09 | | 1.16 (0.89–1.50) | 0.27 |
| Hospital cases per year | | | | | |
| 0–6 | Reference | | | Reference | |
| 7–15 | 1.07 (0.86–1.34) | 0.54 | | 0.91 (0.74–1.12) | 0.391 |
| 16+ | 0.87 (0.66–1.14) | 0.32 | | 0.83 (0.64–1.08) | 0.16 |

CI, confidence interval.
Unweighted n is 23,628 myomectomies in 6,011 hospitals.
Multivariable analysis weighted and adjusted for all patient and hospital characteristics.
Large hospital size was defined as 45 or more beds with variance in size categories by Census region and teaching status.
2014 income quartiles: less than $40,000, $40,000–$50,999, $51,000–$65,999, $66,000 or more.
Subgroup analysis by region showed that African American women had lower odds of undergoing MIM compared to Caucasian women across all regions. In the South and Midwest, women had lower odds of undergoing MIM at teaching hospitals (OR 0.78, 95% CI 0.64–0.95, OR 0.54 95% CI 0.40–0.73 respectively). In the West, women in the highest income brackets had lower odds of undergoing MIM compared to other income brackets (OR 0.65, 95% CI 0.46–0.91). No other statistically significant differences were seen within regions (Table 4).

When the data was limited to only hospitals performing at least one MIM per year (n = 111,390, Appendix A), the findings remained the same. When myomectomies performed during 2014 were excluded to remove any confounding from the 2014 FDA recommendation against power morcellation, the only value that was no longer statistically significant was women in the third quartile income bracket no longer had lower odds of undergoing MIM (Appendix B).

**DISCUSSION**

In our analysis of almost 115,000 women who underwent inpatient myomectomy in the United States, we found significant underutilization of the minimally invasive approach with further racial and regional disparities. African American women were half as likely to undergo MIM after adjustment for other patient and hospital factors.

MIM remains the gold standard for uterine sparing surgery with decreased blood loss and postoperative pain, shorter hospital stays, and faster recovery. Despite these benefits, less than 10% of myomectomies were performed using an MIS approach during the study period. This underutilization may be attributed to the higher costs and/or challenging surgical techniques, including laparoscopic suturing, knot tying, dissection, and extraction of the myoma. Specifically, studies have shown that laparoscopic knot tying is a significant barrier to performing laparoscopy. Therefore, barbed sutures gained popularity in MIM and other gynecologic surgeries.19,20

In our study, African American women underwent most myomectomies but had the lowest proportion of MIM. A large body of research has shown racial disparities in women undergoing hysterectomy,6,12,14 with an independent increase in surgical complications in African American and Asian American women; one study showing an elevated odds of almost every category of medical/surgical complications in African American women as well as risk of readmission.21–23 A 2020 study by Pollack et al. showed that African American, Hispanic, and Asian/Pacific Islander women eligible for minimally invasive hysterectomy were more likely than Caucasian women to undergo an open hysterectomy.24 Another study using the NIS showed that African American women had only half the odds of undergoing MIS hysterectomy after adjusting for patient, clinical, and hospital characteristics.25 The NIS lacks information about pre-operative imaging or specimen weight and the MIM racial disparities in our data could be explained, at least in part, by more complex fibroids (larger and/or higher number) in African American women. However, one prior study on myomectomy showed that African American women are substantially more likely to undergo myomectomy via laparotomy, even when accounting for fibroid burden.15 Fibroid disease severity in African American women would also not account for the MIM disparity seen in other minority groups in our study. These findings highlight the need for further efforts to address disparities, specifically in myomectomy given the higher prevalence and burden of fibroids in African American women making this procedure more common in this racial group.

Women in the Midwest and the West had higher odds of undergoing MIM, which may be correlated to these previously demonstrated racial disparities. According to the United States Census Bureau, the distribution of states with the lowest African American population (< 10%) were the Midwest and West.26 However, in the multivariable analysis, the associations of race and region should be controlled and therefore this relationship is not the sole reason for these findings. Disparities in geographic region may also be related to obesity with lower obesity rates seen in those regions that were more likely to perform MIM.

Our data indicates a lower odds of undergoing MIM with private insurance and higher-income brackets, which contradicts previous hysterectomy data.14 This data may be a limitation of an inpatient database, discussed further below. If same day discharge MIM analysis were also included, this data may in fact show that those patients requiring admission (rather than same day discharge) are those with lower income and public insurance. Further research is needed within this area. The findings regarding lower odds of undergoing MIM at teaching hospitals must be taken with caution, given the broad NIS definition of a teaching hospital (a member of...
### Table 4.
Association of Minimally Invasive Myomectomy with Patient, Hospital, and Gynecologic Characteristics by Region (n = 114,850 Myomectomies)

| Year | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value |
|------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| 2010 | 0.84 (0.74–0.94)    | 0.003   | 0.86 (0.79–0.93)    | < 0.001 | 0.93 (0.82–1.05)    | 0.25    | 0.99 (0.86–1.14)    | 0.86    |
| 2011 |                     |         |                     |         |                     |         |                     |         |
| 2012 |                     |         |                     |         |                     |         |                     |         |
| 2013 |                     |         |                     |         |                     |         |                     |         |
| 2014 |                     |         |                     |         |                     |         |                     |         |

**Patient Characteristics**

| Age          | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value |
|--------------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| 18–20 years  | Reference           |         | Reference           |         | Reference           |         | Reference           |         |
| 21–30 years  | 0.63 (0.08–5.26)    | 0.67    | 1.01 (0.13–8.02)    | 0.99    | 0.44 (0.05–3.97)    | 0.46    | 0.57 (0.07–4.41)    | 0.59    |
| 31–40 years  | 0.48 (0.06–3.91)    | 0.49    | 1.12 (0.14–8.80)    | 0.91    | 0.60 (0.07–5.24)    | 0.64    | 0.70 (0.09–5.34)    | 0.74    |
| 41–50 years  | 1.41 (0.17–11.54)   | 0.75    | 4.33 (0.55–33.91)   | 0.16    | 3.19 (0.37–27.83)   | 0.29    | 2.27 (0.30–17.16)   | 0.43    |

**Race**

| Race         | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value |
|--------------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| Caucasian    | Reference           |         | Reference           |         | Reference           |         | Reference           |         |
| African American | 0.55 (0.43–0.72) | < 0.001 | 0.57 (0.47–0.69)    | < 0.001 | 0.61 (0.44–0.84)    | 0.002   | 0.58 (0.43–0.78)    | < 0.001 |
| Hispanic     | 0.75 (0.52–1.08)   | 0.12    | 0.73 (0.54–0.97)    | 0.03    | 0.48 (0.25–0.96)    | 0.04    | 0.70 (0.53–0.95)    | 0.01    |
| Other race(s)| 0.65 (0.46–0.93)   | 0.02    | 0.67 (0.48–0.93)    | 0.02    | 0.75 (0.46–1.22)    | 0.25    | 0.56 (0.41–0.77)    | < 0.001 |

**Insurance type**

| Insurance type | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value |
|----------------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| Public and Uninsured | Reference |         | Reference           |         | Reference           |         | Reference           |         |
| Private        | 0.90 (0.70–1.16)   | 0.41    | 0.89 (0.73–1.08)    | 0.23    | 0.80 (0.58–1.12)    | 0.20    | 1.10 (0.88–1.50)    | 0.32    |

**Household income**

| Household income | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value |
|------------------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| Lowest quartile  | Reference           |         | Reference           |         | Reference           |         | Reference           |         |
| 2nd quartile     | 0.74 (0.52–1.04)   | 0.08    | 0.95 (0.75–1.19)    | 0.64    | 0.97 (0.67–1.41)    | 0.88    | 1.08 (0.77–1.53)    | 0.64    |
| 3rd quartile     | 0.83 (0.61–1.13)   | 0.23    | 0.87 (0.69–1.10)    | 0.24    | 0.77 (0.53–1.12)    | 0.17    | 0.91 (0.65–1.27)    | 0.58    |
| Highest quartile | 0.84 (0.62–1.14)   | 0.27    | 0.83 (0.65–1.04)    | 0.12    | 0.71 (0.46–1.07)    | 0.103   | 0.65 (0.46–0.91)    | 0.01    |

**Hospital Characteristics**

| Hospital Characteristics | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value |
|--------------------------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| Large hospital           | 0.79 (0.61–1.02)   | 0.07    | 1.06 (0.89–1.26)    | 0.49    | 0.76 (0.57–1.03)    | 0.08    | 0.97 (0.76–1.22)    | 0.78    |
| Teaching hospital        | 0.93 (0.69–1.24)   | 0.62    | 0.78 (0.56–0.95)    | 0.01    | 0.54 (0.40–0.73)    | < 0.001 | 0.88 (0.70–1.11)    | 0.28    |
| For-profit hospital      | 1.72 (0.92–3.24)   | 0.09    | 0.92 (0.74–1.14)    | 0.42    | 0.87 (0.49–1.55)    | 0.64    | 0.81 (0.59–1.10)    | 0.18    |

**Hospital cases per year**

| Hospital cases per year | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value | Odds Ratio (95% CI) | p-value |
|-------------------------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| 0–6                     | Reference           |         | Reference           |         | Reference           |         | Reference           |         |
| 7–15                    | 1.22 (0.91–1.63)   | 0.18    | 0.95 (0.77–1.17)    | 0.62    | 1.24 (0.84–1.83)    | 0.28    | 0.78 (0.60–1.01)    | 0.06    |
| 16+                     | 1.15 (0.79–1.67)   | 0.47    | 0.79 (0.60–1.03)    | 0.08    | 1.19 (0.73–1.95)    | 0.49    | 0.71 (0.51–0.99)    | 0.05    |

CI, confidence interval.
Unweighted n is 23,628 myomectomies in 6,011 hospitals.
Multivariable analysis weighted and adjusted for all patient and hospital characteristics.
Large hospital size was defined as 45 or more beds with variance in size categories by Census region and teaching status.
2014 income quartiles: less than $40,000, $40,000–$50,999, $51,000–$65,999, $66,000 or more.
the Council of Teaching hospital, had a residency program, or had a full-time resident), which accounted for 65% of hospitals in our study.

Lastly, our data indicated that women aged 41–50 had a higher odds of undergoing MIM compared to younger women. Due to the lack of tactile feedback with minimally invasive surgery compared to open surgery, there may be some surgeons who prefer to palpate the uterus if the myomectomy is being performed for future fertility to avoid retention of fibroids. Certain studies do indicate a higher risk of recurrence with laparoscopy versus open technique, although data is conflicting.

There are inherent limitations of a large national database, including coding inconsistencies between hospitals and coding errors. We attempted to account for some coding error by eliminating cases that did not have fibroids listed in the top ten discharge diagnoses. Another significant limitation of this study is an inpatient database which does not account for same-day discharges. However, a literature review of published studies in and around our study period suggests that same day discharge was not as ubiquitous at the time of our study as it is in current times, suggesting our data may be broadly applicable. Studies which specifically explore and report on day of discharge rates are from single, academic, high-volume institutions with a small number of specialized surgeons. One study was between January 1, 2011–December 31, 2013 with same day discharge rates of 88% (N = 403) and another between January 1, 2012–December 31, 2018 with same day discharge rates of 66% (N = 315). There has only been one large National Surgical Quality Improvement Program (NSQUIP) study performed between January 1, 2014–December 31, 2016, which is even beyond our study time period, (N = 7551, ~3000 MIS) with a same day discharge rate of 57.5% among laparoscopic myomectomies. One additional study of laparoscopic and robotic myomectomies performed between January 1, 2016–December 31, 2017 had 57% of patients remain in the hospital for one day, 25% for 2 days, and 2% for 3 days which would indicate a same-day discharge rate of only ~15% (10), albeit a small study. Therefore, one could conclude that MIM rates were lower during our study time frame. Even if one were to double the reported MIM rate in our study to account for the possibly unincluded ~50%–60% discharged same day as evidenced by the large NSQUIP study, the rates of MIM would still be staggeringly low (~14%), although caution must be taken with this direct comparison. One must also caution the low values reported in our paper as this may be a result of fewer myomectomies overall with improvements in medical and surgical management.

Likely causes for the underutilization of MIM include higher surgical costs and the need for advanced MIS skills. There are multiple confounders that make a direct cost comparison of abdominal versus minimally invasive surgeries, as well as laparoscopic versus robotic surgeries a challenge. Historically, abdominal myomectomies were noted to be the least expensive compared with laparoscopic and robotic, however, several studies in gynecologic surgery have shown with increasing expertise in MIS, there are shorter operating times, shorter length of stay, and fewer readmissions which can result in overall lower costs. A recent study demonstrated that the operating room time and the hospital length of stay appear to be potentially modifiable predictors of cost. Another study provided specific strategies to cut waste in the operating room via parallel tasking, minimizing time, and minimizing the number of instruments used. Also, outpatient surgeries appear to be safe with significant cost savings. Simulation appears to be an effective way to improve MIS skills and increase its utilization. First, simulation may improve the quality and safety of surgery. Second, simulation can decrease operating room time which can reduce cost and therefore increase utilization. Current evidence suggests that simulation can affect outcomes. Interestingly, it appears that simulation training in the laparoscopic and robotic platforms affect each other. Even more, it appears that improved spatial and temporal eye-brain-hand coordination from video games may improve performance.

CONCLUSION

In conclusion, MIM not only remains underutilized, but also the underutilization disproportionally affects minority women. Recognition of these racial disparities is a critical first step and demands further investigation and action on a societal level. When feasible, women in need of myomectomy for complex fibroids can be referred to surgeons skilled in MIS techniques to assess their candidacy for an MIS approach. Given the high rate of myomectomy among African American women, referrals become increasingly important for them. Future studies include directly exploring outpatient myomectomy and surgical complications in each of the racial groups while controlling for the fibroid burden.
### Appendix A. Association of MIM with Patient, Hospital, and Gynecologic Characteristics at Hospitals Performing 1 or more MIM (n=111,390 myomectomies)

| Year   | Univariate Analysis | p-value | Multivariate Analysis | p-value |
|--------|---------------------|---------|-----------------------|---------|
|        | Odds Ratio (95% CI) |         |                       |         |
| 2010   | 1.16 (1.03-1.31)    | 0.01    | 0.91 (0.86-0.95)      | <0.001  |
| 2011   | 1.15 (1.02-1.29)    | 0.02    |                       |         |
| 2012   | 0.92 (0.81-1.04)    | 0.18    |                       |         |
| 2013   | 0.97 (0.85-1.11)    | 0.66    |                       |         |
| 2014   | 0.81 (0.70-0.92)    | 0.002   |                       |         |

| Patient Characteristics | Univariate Analysis | p-value | Multivariate Analysis | p-value |
|-------------------------|---------------------|---------|-----------------------|---------|
|                        | Odds Ratio (95% CI) |         |                       |         |
| **Age**                |                     |         |                       |         |
| 18-20 years            | 0.99 (0.36-2.73)    | 0.98    | Reference              |         |
| 21-30 years            | 0.53 (0.45-0.63)    | <0.001  | 0.64 (0.22-1.82)       | 0.40    |
| 31-40 years            | 0.37 (0.33-0.41)    | <0.001  | 0.69 (0.24-1.95)       | 0.48    |
| 41-50 years            | 3.70 (3.34-4.09)    | <0.001  | 2.46 (0.87-6.99)       | 0.09    |
| **Race**               |                     |         |                       |         |
| White                  | 1.81 (1.63-2.00)    | <0.001  | Reference              |         |
| Black                  | 0.62 (0.55-0.68)    | <0.001  | 0.56 (0.50-0.64)       | <0.001  |
| Hispanic               | 1.00 (0.87-1.16)    | 0.98    | 0.69 (0.59-0.82)       | <0.001  |
| Other race(s)          | 0.84 (0.71-0.98)    | 0.03    | 0.62 (0.52-0.74)       | <0.001  |
| **Insurance type**     |                     |         |                       |         |
| Publicly-insured and Uninsured | 1.04 (0.93-1.17) | 0.47    | Reference              |         |
| Privately-insured      | 0.96 (0.85-1.07)    | 0.47    | 0.91 (0.81-1.04)       | 0.16    |
| **Household income**   |                     |         |                       |         |
| Lowest quartile        | 1.06 (0.94-1.18)    | 0.36    | Reference              |         |
| 2nd quartile           | 1.08 (0.96-1.21)    | 0.23    | 0.91 (0.79-1.06)       | 0.23    |
| 3rd quartile           | 0.97 (0.87-1.09)    | 0.65    | 0.83 (0.72-0.96)       | 0.01    |
| Highest quartile       | 0.92 (0.82-1.03)    | 0.13    | 0.74 (0.63-0.85)       | <0.001  |
| **Hospital Characteristics** |                  |         |                       |         |
| Large hospital         | 0.94 (0.85-1.04)    | 0.23    | 0.92 (0.82-1.02)       | 0.12    |
| Teaching hospital      | 0.68 (0.62-0.75)    | <0.001  | 0.78 (0.69-0.87)       | <0.001  |
| For-profit hospital    | 1.04 (0.90-1.21)    | 0.54    | 0.91 (0.78-1.07)       | 0.27    |
| **Region**             |                     |         |                       |         |
| Northeast              | 0.82 (0.73-0.93)    | 0.001   | Reference              |         |
| South                  | 0.86 (0.78-0.95)    | 0.004   | 1.08 (0.93-1.25)       | 0.31    |
| Midwest                | 1.22 (1.06-1.41)    | 0.005   | 1.28 (1.08-1.52)       | 0.005   |
| West                   | 1.31 (1.17-1.47)    | <0.001  | 1.23 (1.04-1.45)       | 0.02    |
| **Hospital volume**    |                     |         |                       |         |
| 0-6 myomectomies per year | 1.30 (1.17-1.44) | <0.001  | Reference              |         |
| 7-15 myomectomies per year | 0.94 (0.84-1.05) | 0.27    | 0.90 (0.79-1.03)       | 0.11    |
| 16+ myomectomies per year | 0.81 (0.73-0.90) | <0.001  | 0.78 (0.67-0.92)       | 0.003   |

Unweighted n is 22,876 myomectomies in 4,537 hospitals performing one or more MIS myomectomy during the study period.

Multivariate analysis is weight and adjusted for all patient, gynecologic diagnosis, and hospital characteristics. 2014 income quartiles: less than $40,000, $40,000–$50,999, $51,000–$65,999, $66,000 or more.

Large hospital size was defined as 45 or more beds with variance in size categories by Census region and teaching status.
Appendix B. Association of MIM with Patient, Hospital, and Gynecologic Characteristics from 2010-2013

|                        | Univariate Analysis | p-value | Multivariate Analysis | P-value |
|------------------------|--------------------|---------|-----------------------|---------|
|                        | Odds Ratio (95% CI) |         | Odds Ratio (95% CI)   |         |
| **Year**               |                    |         |                       |         |
| - 2010                 | 1.14 (1.01-1.29)    | 0.03    | 0.89 (0.83-0.95)      | <0.001  |
| - 2011                 | 1.11 (0.99-1.26)    | 0.08    |                       |         |
| - 2012                 | 0.84 (0.74-0.96)    | 0.01    |                       |         |
| - 2013                 | 0.91 (0.80-1.04)    | 0.17    |                       |         |
| **Patient Characteristics** |                   |         |                       |         |
| **Age**                |                    |         |                       |         |
| - 18-20 years          | 1.06 (0.38-2.95)    | 0.91    | Reference             |         |
| - 21-30 years          | 0.54 (0.45-0.65)    | <0.001  | 0.60 (0.21-1.72)      | 0.34    |
| - 31-40 years          | 0.37 (0.33-0.41)    | <0.001  | 0.62 (0.22-1.78)      | 0.38    |
| - 41-50 years          | 3.71 (3.32-4.14)    | <0.001  | 2.270336              | 0.13    |
|                        | 1.214196            |         | 1.53                  |         |
|                        | 6.47663             |         | 0.125                 |         |
|                        | 0.79585             |         | 6.47663               |         |
| **Race**               |                    |         |                       |         |
| - White                | 1.73 (1.55-1.93)    | <0.001  | Reference             |         |
| - Black                | 0.63 (0.57-0.71)    | <0.001  | 0.59 (0.52-0.67)      | <0.001  |
| - Hispanic             | 0.97 (0.83-1.14)    | 0.71    | 0.70 (0.59-0.85)      | <0.001  |
| - Other race(s)        | 0.88 (0.74-1.05)    | 0.16    | 0.66 (0.55-0.80)      | <0.001  |
| **Insurance type**     |                    |         |                       |         |
| - Publicly-insured and Uninsured | 0.97 (0.85-1.10) | 0.61    | Reference             |         |
| - Privately-insured    | 1.03 (0.91-1.17)    | 0.61    | 0.93 (0.81-1.07)      | 0.29    |
| **Household income**   |                    |         |                       |         |
| - Lowest quartile      | 1.07 (0.94-1.21)    | 0.31    | Reference             |         |
| - 2nd quartile         | 1.06 (0.93-1.21)    | 0.36    | 0.91 (0.78-1.08)      | 0.29    |
| - 3rd quartile         | 1.01 (0.90-1.15)    | 0.82    | 0.87 (0.74-1.02)      | 0.09    |
| - Highest quartile     | 0.89 (0.78-1.00)    | 0.05    | 0.73 (0.62-0.86)      | <0.001  |
| **Hospital Characteristics** |               |         |                       |         |
| - Large hospital       | 1.01 (0.90-1.13)    | 0.91    | 0.99 (0.88-1.12)      | 0.89    |
| - Teaching hospital    | 0.75 (0.67-0.84)    | <0.001  | 0.83 (0.73-0.95)      | 0.005   |
| - For-profit hospital  | 1.03 (0.87-1.20)    | 0.76    | 0.91 (0.76-1.08)      | 0.29    |
| **Region**             |                    |         |                       |         |
| - Northeast            | 0.83 (0.73-0.94)    | 0.005   | Reference             |         |
| - South                | 0.85 (0.76-0.95)    | 0.004   | 1.09 (0.93-1.28)      | 0.30    |
| - Midwest              | 1.26 (1.08-1.47)    | 0.003   | 1.34 (1.11-1.62)      | 0.002   |
| - West                 | 1.31 (1.15-1.48)    | <0.001  | 1.26 (1.05-1.50)      | 0.01    |
| **Hospital volume**    |                    |         |                       |         |
| - 0-6 myomectomies per year | 1.23 (1.09-1.37) | <0.001  | Reference             |         |
| - 7-15 myomectomies per year | 1.01 (0.90-1.14) | 0.81    | 0.95 (0.82-1.10)      | 0.51    |
| - 16+ myomectomies per year | 0.81 (0.73-0.91) | <0.001  | 0.81 (0.68-0.96)      | 0.02    |

Unweighted n is 19,118 myomectomies in 6,011 hospitals
Multivariate analysis is weight and adjusted for all patient, gynecologic diagnosis, and hospital characteristics. 2014 income quartiles: less than $40,000, $40,000–50,999, $51,000–65,999, $66,000 or more. Large hospital size was defined as 45 or more beds with variance in size categories by Census region and teaching status.
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