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Long-Term Risk of Reintervention After Surgical Leiomyoma Treatment in an Integrated Health Care System

Susanna D. Mitro, PhD, Fei Xu, MS, Catherine Lee, PhD, Eve Zaritsky, MD, L. Elaine Waetjen, MD, Lauren A. Wise, ScD, and Monique M. Hedderson, PhD

OBJECTIVE: To compare long-term risk of reintervention across four uterus-preserving surgical treatments for leiomyomas and to assess effect modification by sociodemographic factors in a prospective cohort study in an integrated health care delivery system.

METHODS: We studied a cohort of 10,324 patients aged 18–50 (19.9% Asian, 21.2% Black, 21.3% Hispanic, 32.5% White, 5.2% additional races and ethnicities) who had a first uterus-preserving procedure (abdominal, laparoscopic, or vaginal myomectomy [referred to as myomectomy]; hysteroscopic myomectomy; endometrial ablation; uterine artery embolization) after leiomyoma diagnosis in the 2009–2021 electronic health records of Kaiser Permanente Northern California. We followed up patients until reintervention (second uterus-preserving procedure or hysterectomy) or censoring. We used a Kaplan–Meier estimator to calculate the cumulative incidence of reintervention and Cox regression models to estimate hazard ratios and 95% CIs comparing rates of reintervention across procedures, adjusting for age, parity, race and ethnicity, body mass index (BMI), Neighborhood Deprivation Index, and year. We also assessed effect modification by demographic characteristics.

RESULTS: Median follow-up was 3.8 years (interquartile range 1.8–7.4 years). Index procedures were 18.0% (1,857) hysteroscopic myomectomies, 16.2% (1,669) uterine artery embolizations, 21.4% (2,211) endometrial ablations, and 44.4% (4,587) myomectomies. Accounting for censoring, the 7-year reintervention risk was 20.6% for myomectomy, 26.0% for uterine artery embolization, 35.5% for endometrial ablation, and 37.0% for hysteroscopic myomectomy; 63.2% of reinterventions were hysterectomies. Within each procedure type, reintervention rates did not vary by BMI, race and ethnicity, or Neighborhood Deprivation Index. However, rates of reintervention after uterine artery embolization, endometrial ablation, and hysteroscopic myomectomy decreased with age, and reintervention rates for hysteroscopic myomectomy were higher for parous than nulliparous patients.

CONCLUSION: Long-term reintervention risks for uterine artery embolization, endometrial ablation, and hysteroscopic myomectomy are greater than for myomectomy, with potential variation by patient age and parity but not BMI, race and ethnicity, or Neighborhood Deprivation Index.

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See related editorial on page 609.

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Uterine leiomyomas (leiomyoma) are benign tumors of the uterus. In 2012, leiomyomas were estimated to cost up to $9.4 billion annually (in 2010 dollars) to

treat with surgeries, medications, and procedures.[1] However, a 2017 comparative-effectiveness review from the Agency for Healthcare Research and Quality reported that the evidence on leiomyoma treatments was insufficient to guide clinical care, and few well-conducted trials of leiomyoma treatment have directly compared different treatment options.[2] Clinicians and patients therefore currently rely mostly on small studies with short follow-up, high losses to follow-up, or non-generalizable participants as the basis for clinical decision making.[3–5] The sparse evidence on long-term outcomes specifically in Black patients constitutes a major gap; preliminary data suggest that Black patients may have higher posttreatment rates of leiomyoma recurrence than White patients.[6]

In a large integrated health care delivery system with excellent retention[7] serving a racially diverse patient population, we compared long-term reintervention risk among four uterus-preserving leiomyoma treatments (myomectomy, hysteroscopic myomectomy, uterine artery embolization, and endometrial ablation) and evaluated the extent to which reintervention risk varied by race and ethnicity, age, body mass index (BMI, calculated as weight in kilograms divided by height in meters squared), parity, and Neighborhood Deprivation Index.

METHODS

Kaiser Permanente Northern California is an integrated health care delivery system providing comprehensive health care for more than 30% of Northern California residents. All care is captured in the electronic health record (EHR). Details about the Kaiser Permanente Northern California system have been published previously.[8]

Patients in this prospective cohort analysis had a uterus-preserving leiomyoma procedure between January 1, 2009, and December 31, 2021; had a diagnosis of uterine leiomyomas (International Classification of Diseases [ICD], Ninth Revision code 218.*; ICD, 10th Revision code D25.*); had no record of prior hysterectomy; were Kaiser Permanente Northern California members for at least 1 year before and 1 year after treatment; and were 18–50 years of age at the first (index) uterus-preserving procedure. Patients who were pregnant or within 6 weeks postpartum at the index procedure (3.2%) were excluded. This study was approved by the Kaiser Permanente Northern California IRB. The requirement for informed consent was waived.

Uterus-preserving procedures were myomectomy (abdominal, vaginal, or laparoscopic), uterine artery embolization, endometrial ablation, or hysteroscopic myomectomy, identified by ICD and Current Procedural Terminology codes (Appendix 1, available online at http://links.lww.com/AOG/D616). Patients with more than one type of index procedure on the same day were excluded.

We defined a *reintervention* as a second uterus-preserving procedure or a hysterectomy (identified by ICD and Current Procedural Terminology codes; Appendix 2, available online at http://links.lww.com/AOG/D616) more than 30 days after the index uterus-preserving procedure. Patient demographic and clinical factors (age, race and ethnicity, parity, BMI, and Neighborhood Deprivation Index [a composite variable reflecting Census tract–level socioeconomic status[9]]) were obtained from the EHRs from the year before the index procedure. Patients self-identified race and ethnicity, which we categorized into groups (Asian, Black, Hispanic, White, and additional races and ethnicities [multiracial, Native American, Pacific Islander]); we included race in this study because there are known racial disparities in leiomyoma burden[10] that may translate to differences in reintervention risks. Symptoms (excessive or irregular bleeding, dyspareunia, pelvic or lower abdominal pain, dysmenorrhea, and urinary incontinence) were identified with ICD codes (Appendix 3, available online at http://links.lww.com/AOG/D616).

Patients were followed up from the index uterus-preserving procedure until December 31, 2022; end of Kaiser Permanente Northern California membership; or reintervention. We used a Kaplan–Meier estimator to calculate unadjusted cumulative incidence of reintervention.

We used Cox proportional hazards models to estimate hazard ratios (HRs) and 95% CIs comparing relative rates of reintervention for uterine artery embolization and endometrial ablation with myomectomy. Models were adjusted for age at index procedure (18–35, 36–40, 41–45, 46–50 years), race and ethnicity (Asian, Black, Hispanic, White, additional races and ethnicities), parity (nulliparous, primiparous, multiparous), BMI (lower than 25.0, 25.0–29.9, 30.0–34.9, 35.0 or higher), quartile of Neighborhood Deprivation Index, and year of index procedure (2009–2021). We did not compare relative reintervention rates after hysteroscopic myomectomy with myomectomy because differing indications limit the number of patients who may have the opportunity to choose between these two procedures.

To calculate reintervention rates after 1, 3, 4, and 7 years, we censored participants and fitted separate models for each time horizon. To understand whether each procedure was equally effective across subgroups,

we compared rates of reintervention after each procedure by age, race and ethnicity, parity, BMI, and Neighborhood Deprivation Index. Finally, to compare patients with similar symptoms, we restricted our analysis to patients with bleeding or pain symptoms.

To ensure that index procedures were conducted to treat leiomyomas, we restricted our analysis to patients who had a linked leiomyoma diagnosis code on the day of the index procedure (79.4% of procedures). We additionally compared rates of reintervention after abdominal, laparoscopic, and vaginal myomectomies performed from 2016 to 2021 (n=272 abdominal, 1,487 laparoscopic, and 163 vaginal myomectomies; years chosen because of data availability). Analyses were conducted in SAS 9.4.

RESULTS

Median follow-up was 3.8 years (interquartile range 1.8–7.4 years, 90th percentile 11.1 years, maximum 14.0 years). Index procedures were 18.0% hysteroscopic myomectomy, 16.2% uterine artery embolization, 21.4% endometrial ablation, and 44.4% myomectomy. The population was diverse in race and ethnicity, parity, BMI, and age (Table 1).

Accounting for censoring, 1-year reintervention risk was 4.3% for myomectomy, 8.0% for uterine artery embolization, 13.5% for endometrial ablation, and 15.9% for hysteroscopic myomectomy in unadjusted models, which increased to 20.6% for myomectomy, 26.0% for uterine artery embolization, 35.5% for endometrial ablation, and 37.0% for hysteroscopic myomectomy by 7 years. Among patients with reintervention, 63.2% underwent hysterectomy, 19.2% underwent a second procedure of the same type as their index procedure, and 17.6% underwent a second uterus-preserving procedure of a different type from their index procedure (Table 2). Cumulative reintervention rates among patients with bleeding symptoms were slightly higher, whereas reintervention rates among patients with pain symptoms were similar to the all-patient reintervention rate for each procedure (Appendix 4, available online at http://links.lww.com/AOG/D616).

In adjusted models, rates of reintervention were higher for endometrial ablation and uterine artery embolization compared with myomectomy at 1, 3, 5, and 7 years and over all follow-up time after the index procedure. Within the first year after the index procedure, patients who underwent endometrial ablation were 3 times more likely to have a reintervention (HR 2.97, 95% CI, 2.33–3.79); patients who underwent uterine artery embolization were 82% more likely (HR 1.82, 95% CI, 1.39–2.37) to have a reintervention than patients who underwent myomectomy (Table 3). At 7 years after the index procedure, patients who underwent endometrial ablation were more than twice as likely to have a reintervention (HR 2.27, 95% CI, 1.97–2.62); patients who underwent uterine artery embolization were 52% more likely to have a reintervention (HR 1.52, 95% CI, 1.30–1.78) compared with patients who underwent myomectomy (Table 3). Results were similar among patients with pain symptoms, although elevated relative rates of reintervention after uterine artery embolization and endometrial ablation compared with myomectomy were somewhat attenuated among patients with bleeding symptoms (Table 3).

Reintervention risk did not vary by race and ethnicity, BMI, or Neighborhood Deprivation Index (Figs. 1 and 2) (Appendices 5 and 6, available online at http://links.lww.com/AOG/D616). Rates of reintervention after uterine artery embolization, endometrial ablation, and hysteroscopic myomectomy varied by age, with patients aged 18–35 at the index procedure having 1.4–3.7 times greater rates of reintervention than patients aged 46–50. Reintervention rates for hysteroscopic myomectomy varied by parity: reintervention rates among multiparous patients compared with nulliparous patients were 35% greater (Fig. 2) (Appendix 6, http://links.lww.com/AOG/D616).

Analyses restricted to patients with a leiomyoma diagnosis on the day of the index procedure were similar to main models (Appendix 7, available online at http://links.lww.com/AOG/D616). Compared with index laparoscopic myomectomy, rates of reintervention after vaginal and abdominal myomectomy were elevated (HR 2.32, 95% CI, 1.28–4.20; and HR 1.27, 95% CI, 0.80–2.01, respectively; Appendix 8, available online at http://links.lww.com/AOG/D616).

DISCUSSION

Among patients with a leiomyoma diagnosis and initial uterus-preserving procedure in a large and racially diverse integrated health care delivery system, we found that myomectomy was associated with lower rates of reintervention than endometrial ablation, uterine artery embolization, and hysteroscopic myomectomy over more than 7 years of follow-up. Reintervention rates did not vary by BMI, race and ethnicity, or Neighborhood Deprivation Index but were higher among younger patients after uterine artery embolization, endometrial ablation, and hysteroscopic myomectomy and for parous patients after hysteroscopic myomectomy. Findings may be a useful

Table 1. Index Uterus-Preserving Surgical Leiomyoma Treatment by Demographic Factors Among Kaiser Permanente Northern California Patients, 2009–2021 (N=10,324)

Characteristic	Overall (N=10,324)	Endometrial Ablation [n=2,211 (21.4)]	Hysteroscopic Myomectomy [n=1,857 (18.0)]	Myomectomy [n=4,587 (44.4)]	UAE [n=1,669 (16.2)]	*P**
Age (y)						<.001
18–35	1,962 (19.0)	68 (3.1)	317 (17.1)	1,516 (33.1)	61 (3.7)	
36–40	2,513 (24.3)	311 (14.1)	452 (24.3)	1,544 (33.7)	206 (12.3)	
41–45	3,095 (30.0)	841 (38.0)	583 (31.4)	1,026 (22.4)	645 (38.7)	
46–50	2,754 (26.7)	991 (44.8)	505 (27.2)	501 (10.9)	757 (45.4)	
Race and ethnicity						<.001
Asian	2,023 (19.9)	254 (11.6)	379 (20.7)	1,087 (24.1)	303 (18.4)	
Black	2,160 (21.2)	325 (14.8)	241 (13.2)	1,062 (23.5)	532 (32.2)	
Hispanic	2,172 (21.3)	524 (23.9)	495 (27.1)	847 (18.8)	306 (18.5)	
White	3,311 (32.5)	984 (44.8)	644 (35.2)	1,277 (28.3)	406 (24.6)	
Additional races and ethnicities†	527 (5.2)	110 (5.0)	69 (3.8)	244 (5.4)	104 (6.3)	
Unknown or missing	131					
Parity						<.001
0	4,286 (43.7)	292 (13.7)	736 (41.1)	2,842 (65.4)	416 (26.8)	
1	1,770 (18.0)	347 (16.3)	324 (18.1)	731 (16.8)	368 (23.7)	
2 or more	3,764 (38.3)	1,494 (70.0)	730 (40.8)	774 (17.8)	766 (49.4)	
Unknown or missing	504					
BMI (kg/m^2)						<.001
Lower than 25.0	3,393 (33.6)	542 (24.8)	665 (36.8)	1,698 (37.7)	488 (30.1)	
25.0–29.9	3,089 (30.5)	672 (30.8)	536 (29.7)	1,373 (30.5)	508 (31.4)	
30.0–34.9	1,877 (18.6)	482 (22.1)	309 (17.1)	754 (16.7)	332 (20.5)	
35 or higher	1,754 (17.3)	488 (22.3)	296 (16.4)	678 (15.1)	292 (18.0)	
Unknown or missing	211					
NDI						<.001
Least deprived	2,484 (24.1)	433 (19.6)	492 (26.5)	1,170 (25.5)	389 (23.3)	
Second quartile	3,025 (29.3)	651 (29.4)	593 (31.9)	1,287 (28.1)	494 (29.6)	
Third quartile	2,896 (28.1)	698 (31.6)	480 (25.9)	1,268 (27.7)	450 (27.0)	
Most deprived	1,916 (18.6)	429 (19.4)	292 (15.7)	859 (18.7)	336 (20.1)	
Unknown or missing	3					
Symptoms‡						
No recorded symptoms	2,643 (25.6)	91 (4.1)	465 (25.0)	1,655 (36.1)	432 (25.9)	<.001
Excessive or irregular bleeding	6,309 (61.1)	2,056 (93.0)	1,253 (67.5)	1,973 (43.0)	1,027 (61.5)	<.001
Dyspareunia	195 (1.9)	13 (0.6)	22 (1.2)	133 (2.9)	27 (1.6)	<.001
Pelvic or lower abdominal pain	2,299 (22.3)	357 (16.2)	322 (17.3)	1,265 (27.6)	355 (21.3)	<.001
Dysmenorrhea	1,491 (14.4)	371 (16.8)	236 (12.7)	668 (14.6)	216 (12.9)	.001
Urinary incontinence	289 (2.8)	96 (4.3)	42 (2.3)	92 (2.0)	59 (3.5)	<.001
Year (n, row %)						<.001
2009	949	28.7	2.4	45.0	23.9	
2010	1,012	25.8	0.4	45.9	28.0	
2011	895	30.2	12.0	41.6	16.3	
2012	863	23.8	18.2	42.5	15.5	
2013	810	22.5	20.3	43.0	14.3	
2014	785	23.7	17.1	45.6	13.6	
2015	768	19.8	24.0	42.8	13.4	
2016	694	23.2	25.7	39.9	11.2	
2017	784	18.6	25.5	42.6	13.3	
2018	697	16.5	26.1	45.8	11.6	
2019	780	15.0	25.6	45.4	14.0	
2020	538	11.0	26.8	50.6	11.7	
2021	749	11.4	24.0	48.9	15.8	

UAE, uterine artery embolization; BMI, body mass index; NDI, Neighborhood Deprivation Index.
Data are n (%) unless otherwise specified.
* *P* values from χ^2 tests comparing the four uterus-preserving treatments.
† Multiracial, Native American, or Pacific Islander.
‡ Numbers will not sum to the total population because patients may have multiple recorded types of symptoms.

Table 2. Follow-Up Time, Reintervention Rate, and First Reintervention Type by Index Uterus-Preserving Surgical Treatment Among Kaiser Permanente Northern California Patients (N=10,324)

Characteristic	Overall (N=10,324)	Index Procedure				P*
		Endometrial Ablation (n=2,211)	Hysteroscopic Myomectomy (n=1,857)	Myomectomy (n=4,587)	UAE (n=1,669)	
Follow-up time (y)						
Overall	3.8 (1.8–7.4)	4.0 (1.6–8.2)	3.0 (1.3–5.6)	4.1 (2.0–7.6)	4.0 (1.8–8.6)	<.001
Among patients with reintervention	1.6 (0.6–3.4)	1.4 (0.6–2.8)	1.0 (0.4–2.3)	2.6 (1.0–5.1)	1.8 (0.7–3.2)	<.001
Among patients without a reintervention	4.8 (2.3–8.6)	6.1 (3.2–9.9)	4.0 (2.1–6.7)	4.5 (2.2–8.2)	5.3 (2.3–10.0)	<.001
Reintervention rate†						<.001
1 y	907 (8.9)	297 (13.5)	287 (15.9)	194 (4.3)	129 (8.0)	
3 y	1,693 (17.9)	547 (26.1)	473 (27.9)	410 (9.9)	263 (17.6)	
5 y	2,062 (23.6)	648 (32.4)	534 (33.7)	561 (15.5)	319 (22.7)	
7 y	2,251 (27.7)	687 (35.5)	557 (37.0)	660 (20.6)	347 (26.0)	
First reintervention type [n (column %)]‡						<.001
Endometrial ablation	122 (5.1)	46 (6.4)	38 (6.7)	27 (3.6)	11 (3.0)	
Hysteroscopic myomectomy	310 (12.9)	13 (1.8)	182 (32.0)	102 (13.5)	13 (3.6)	
Myomectomy	308 (12.8)	16 (2.2)	67 (11.8)	199 (26.4)	26 (7.2)	
UAE	128 (5.3)	30 (4.2)	21 (3.7)	47 (6.2)	30 (8.3)	
Hysterectomy	1,518 (63.2)	610 (85.2)	251 (44.2)	375 (49.7)	282 (77.9)	

UAE, uterine artery embolization.
Data are median (interquartile range) or n (%) unless otherwise specified.
* *P* values comparing the four uterus-preserving procedures were generated with Kruskal–Wallis tests (for follow-up time), log-rank tests (for reintervention rate), and χ^2 tests (for first reintervention type).
† Reintervention rates are cumulative and were calculated with a Kaplan–Meier estimator to account for varying duration of follow-up. The cumulative number of participants censored by the end of each time period were as follows: year 1 n=143, year 3, n=2,527, year 5 n=4,130, and year 7 n=5,463.
‡ Includes only patients with a single type of reintervention on the date of the first reintervention (15 patients had more than one reintervention type at the time of first reintervention).

Table 3. Relative Rates of Reintervention by 1, 3, 5, and 7 Years and All Follow-Up Time After the Index Uterus-Preserving Treatment, Comparing Patients Who Underwent Index Endometrial Ablation or Uterine Artery Embolization With Patients Who Underwent Index Myomectomy*

Index Procedure	1 y	3 y	5 y	7 y	All Follow-Up Time†
All patients					
Myomectomy	Ref	Ref	Ref	Ref	Ref
UAE	1.82 (1.39–2.37)	1.81 (1.51–2.19)	1.62 (1.37–1.91)	1.52 (1.30–1.78)	1.42 (1.22–1.66)
Endometrial ablation	2.97 (2.33–3.79)	2.72 (2.29–3.22)	2.45 (2.11–2.85)	2.27 (1.97–2.62)	2.16 (1.89–2.48)
Among patients with recorded excessive or irregular bleeding					
Myomectomy	Ref	Ref	Ref	Ref	Ref
UAE	1.34 (0.98–1.82)	1.29 (1.03–1.62)	1.22 (1.00–1.50)	1.18 (0.97–1.43)	1.12 (0.93–1.35)
Endometrial ablation	2.10 (1.61–2.74)	1.99 (1.65–2.41)	1.88 (1.58–2.23)	1.76 (1.49–2.07)	1.68 (1.44–1.96)
Among patients with recorded pelvic or lower abdominal pain					
Myomectomy	Ref	Ref	Ref	Ref	Ref
UAE	2.57 (1.49–4.42)	2.14 (1.45–3.17)	1.72 (1.22–2.44)	1.66 (1.20–2.32)	1.65 (1.20–2.26)
Endometrial ablation	3.35 (1.97–5.71)	3.08 (2.13–4.46)	2.48 (1.79–3.44)	2.36 (1.73–3.22)	2.32 (1.72–3.14)

Ref, reference; UAE, uterine artery embolization.
Data are hazard ratio (95% CI).
* Estimates from Cox proportional hazards models adjusted for age at index procedure, race and ethnicity, parity, body mass index, Neighborhood Deprivation Index, and year of index procedure. Models exclude patients with index hysteroscopic myomectomy because indications for hysteroscopic myomectomy and myomectomy have little overlap. Patients with both pain and bleeding (n=1,214) are included in both the bleeding and pain subanalyses.
†Maximum follow-up is 14 years.

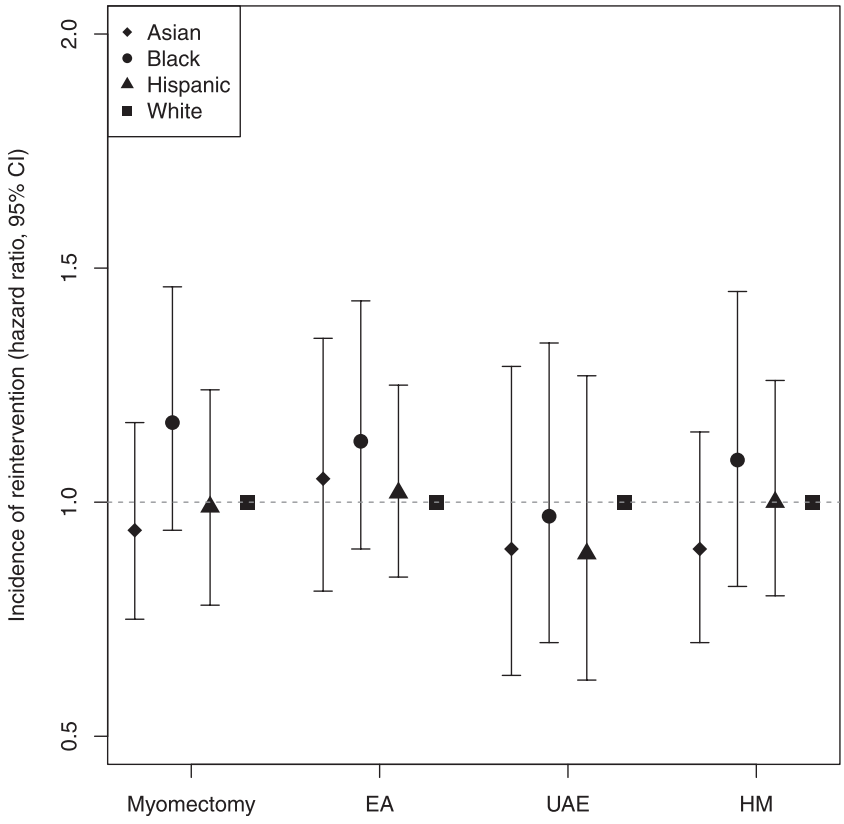

Fig. 1. Relative incidence of reintervention after myomectomy, endometrial ablation (EA), uterine artery embolization (UAE), and hysteroscopic myomectomy (HM) for Asian, Black, and Hispanic patients vs White patients. Estimates are from Cox proportional hazards models stratified by procedure and adjusted for age at index procedure, race and ethnicity, parity, body mass index, Neighborhood Deprivation Index, and year of index procedure. Plotted values are listed in Appendix 5 (available online at http://links.lww.com/AOG/D616).

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reference to discuss expectations for treatment outcomes when choosing initial uterus-preserving treatment for leiomyomas, especially for patients receiving treatment years before the likely onset of menopause.

Our finding that patients with myomectomy have a lower risk of reintervention than patients with uterine artery embolization, endometrial ablation, and hysteroscopic myomectomy is broadly consistent with previous findings and extends prior research by directly comparing reintervention risk over more than 7 years of follow-up time.[3–5] Another recent study with 7 years of follow-up reported that risk of uterus-preserving reintervention was 1.4 times greater and risk of hysterectomy was 2.4 times greater after uterine artery embolization compared with myomectomy,[11] similar to our findings over all follow-up time. Reintervention rates may be lower after myomectomy because some otherwise asymptomatic patients pursue myomectomy to treat infertility. Alternatively, myomectomy may more completely remove leiomyomas than other procedures.

Few previous studies have evaluated racial and ethnic variation in risk of reintervention, and findings are mixed, with one study reporting 12–21% lower odds for Black compared with White patients,[12] another reporting 13% higher odds (but with a wide CI),[6] and a third reporting no relationship between race and reoperation.[13] Black women experience earlier onset and greater leiomyoma prevalence,[14] greater leiomyoma growth, and more severe symptoms than White women,[10] so it is unexpected that reintervention rates were not elevated for Black patients. Reintervention is a crude measure of recurrent or persistent symptoms after uterus-preserving treatment; it is possible that Black, Hispanic, and Asian patients experiencing symptoms may be less likely than White patients to seek surgical reintervention because of mistrust of or frustration with the medical system,[15,16] cost barriers,[17] desire to avoid hysterectomy,[18] or other reasons. However, our findings provide reassurance that these procedures produce broadly equivalent outcomes among patients of all racial and ethnic backgrounds in the Kaiser Permanente Northern California setting, where all patients have health insurance ensuring a baseline level of access to care. In a different context with varying insurance status, insurance type (eg, having Medicaid insurance vs commercial insurance) may affect the timing and type of initial treatments.[19]

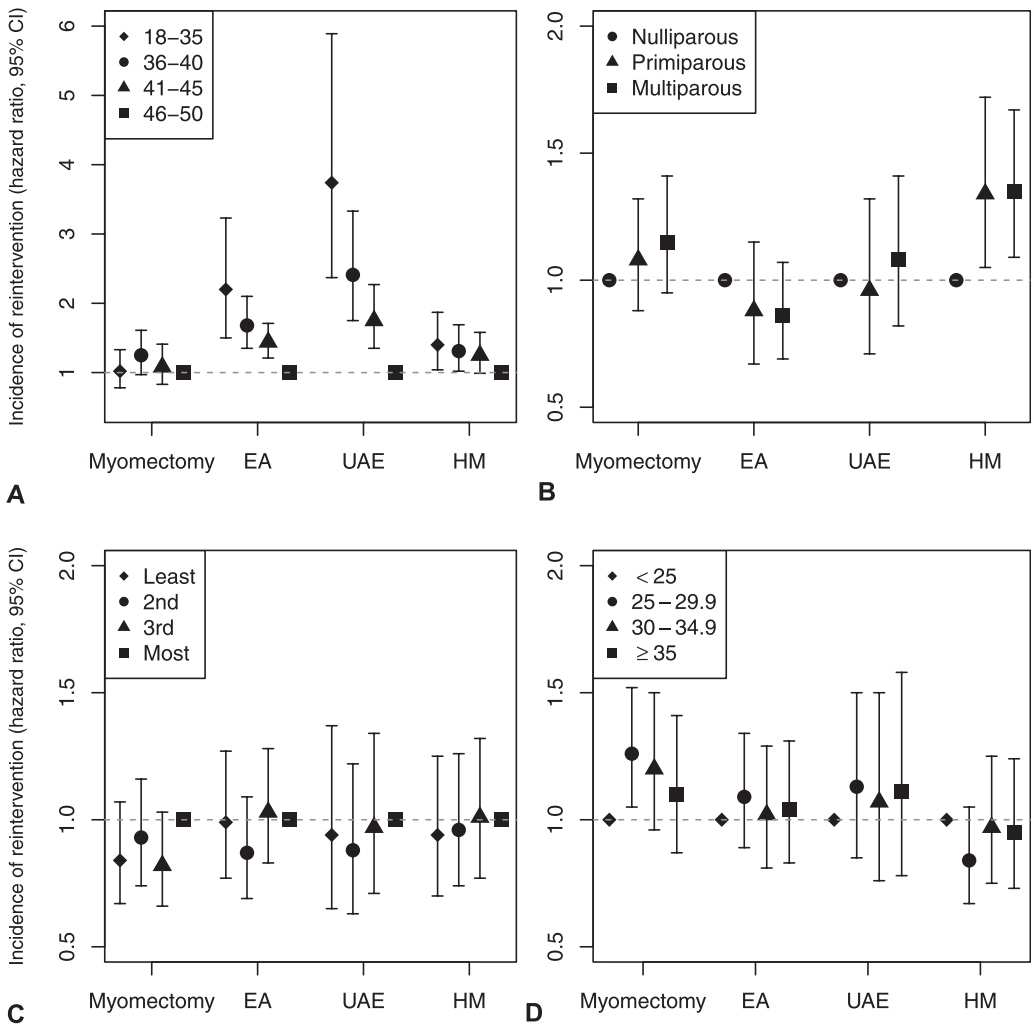

Fig. 2. Relative incidence of reintervention after myomectomy, endometrial ablation (EA), uterine artery embolization (UAE), and hysteroscopic myomectomy (HM) for subgroups of age **(A)**, parity **(B)**, Neighborhood Deprivation Index **(C)**, and body mass index (BMI) **(D)**. Estimates are from Cox proportional hazards models stratified by procedure and adjusted for age at index procedure, race and ethnicity, parity, BMI, Neighborhood Deprivation Index, and year of index procedure. Plotted values are listed in Appendix 6 (available online at http://links.lww.com/AOG/D616).

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Our finding that younger patients had greater risk of reintervention than patients aged 46–50 is generally consistent with prior evidence.[5,11,12,20] Leiomyoma symptom recurrence may be less common among older patients, perhaps because of the onset of menopause. Alternatively, findings may be explained by age-specific care strategies: older patients experiencing symptom recurrence may prefer to wait until the onset of menopause[21] rather than pursuing another surgical treatment.

Strengths of this analysis include our use of Kaiser Permanente Northern California's EHRs, which reflect the experiences of a highly diverse cohort of patients and permitted excellent long-term follow-up with complete capture of reinterventions occurring within Kaiser Permanente Northern California, as well as near-complete demographic information. In addition, the large sample size enabled us to directly compare reintervention rates after four common uterus-preserving treatments.

This study also had limitations. We could not determine procedure indications, although analyses restricted to patients with a leiomyoma diagnosis on the day of the index procedure and to patients with bleeding or pain symptoms were consistent with the main analyses. We did not have details about patients' leiomyomas, disease duration, or fertility desire, which may influence both index treatment and

reintervention. Reintervention rates could therefore reflect unmeasured variation in disease severity in addition to treatment effectiveness; however, patients entered the study at their first uterus-preserving treatment, potentially limiting heterogeneity in disease severity.

Over more than 7 years of follow-up, we found that reintervention rates were lowest after myomectomy, followed by uterine artery embolization, endometrial ablation, and hysteroscopic myomectomy. Reintervention risk did not vary by BMI, race and ethnicity, or Neighborhood Deprivation Index but did vary for some procedures by age and parity. Findings illustrate clinically meaningful long-term differences in reintervention rates after a first uterus-preserving treatment for leiomyomas.

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