



Association between method of pelvic organ prolapse repair involving the vaginal apex and re-operation: a population-based, retrospective cohort study

You (Maria) Wu¹ · Jennifer Reid² · Queena Chou¹ · Barry MacMillan¹ · Yvonne Leong¹ · Blayne Welk^{2,3,4}

Received: 9 August 2018 / Accepted: 8 October 2018 / Published online: 16 October 2018

© The International Urogynecological Association 2018

Abstract

Introduction and hypothesis Vaginal apical suspension is essential for the surgical treatment of pelvic organ prolapse (POP). We aim to evaluate whether the method of apical repair is associated with different re-operation rates for POP recurrence or surgical complications.

Methods Population-based, retrospective cohort study of all Ontario women receiving primary apical POP repairs from 2003 to 2015. Primary exposure was the method of apical POP repair. Primary outcome was re-operation for recurrent POP, and secondary outcomes were surgical procedures for genito-intestinal (GI) or genitourinary (GU) complications, fistula repair, and mesh revision or removal.

Results Forty-three thousand four hundred fifty-eight women were included. Overall, the number of mesh-based apical repairs decreased over time, while the number of native-tissue repairs slightly increased ($p < 0.001$). Multivariable Cox proportional hazards (Cox PH) analysis demonstrated a significant increase in repeat POP operations for transvaginal mesh apical repairs (adjusted HR 1.28 [95% CI: 1.10–1.48]), but not in abdominal mesh repairs (adjusted HR 0.96 [95% CI: 0.81–1.13]) compared with vaginal native tissue apical repairs. Overall risk of repeat surgery for fistulas or GI and GU complications remained low ($< 0.5\%$). Risk of mesh removal or revision was 11.5–11.9%, with no difference between abdominal versus vaginal mesh on multivariable analysis (adjusted HR 0.99 [95% CI: 0.78–1.26]).

Conclusions Re-operation for recurrent POP is highest in transvaginal mesh apical repairs; however, this risk did not differ between abdominal mesh and vaginal native tissue apical repairs. GI and GU re-operations are rare. There is no difference in mesh removal or revision rates between abdominal and vaginal mesh repairs.

Keywords Apical repair · Pelvic organ prolapse · Mesh use · Re-operation

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s00192-018-3792-2>) contains supplementary material, which is available to authorized users.

✉ You (Maria) Wu
ymariawu@gmail.com

¹ Department of Obstetrics and Gynecology, London Health Sciences Centre, Victoria Hospital, Room B4-401, 800 Commissioners Road, East London, ON N6H 5W9, Canada

² Institute for Clinical Evaluative Sciences, Toronto, ON, Canada

³ Department of Epidemiology and Biostatistics, London Health Sciences Centre, London, ON, Canada

⁴ Department of Surgery, London Health Sciences Centre, London, ON, Canada

Introduction

Pelvic organ prolapse (POP) affects 30–40% of women in their lifetime [1] and may have detrimental impacts on women's quality of life. Surgery for POP is often indicated when conservative therapies fail. Adequate support of the vaginal apex is increasingly recognized as the essential component of a durable POP repair [2, 3], since repair of the anterior or posterior compartment alone in the setting of severe POP is associated with a higher failure rate. As such, the number of POP repairs involving vaginal apex fixation has steadily increased over the past 2 decades [4].

Vaginal apical suspension can be achieved using multiple techniques, including abdominal sacrocolpopexy (ASCP), sacrospinous ligament suspension (SSLS), uterosacral ligament fixation (USLF) and McCall culdoplasty. Among these, ASCP has long been regarded as the gold standard for vaginal apical

repairs because of its high anatomical success and durability [5]. Modification to the ASCP, such as laparoscopic lateral mesh suspension, has also been described with a high success and low re-intervention rate [6]. In addition to these approaches, transvaginal mesh (TVM) repair with concurrent apical suspension with or without the use of commercial kits gained popularity before the FDA classified TVM as a high-risk device in 2011 [7, 8]. The use of any vaginal mesh for apical prolapse repair has therefore become controversial because of its association with complications including mesh erosion into adjacent organs, severe pain and repeat surgical interventions [9]. Specifically, mesh erosion rates as high as 16.5% at 3 months post-transvaginal mesh insertion for POP have been reported, with no difference in cure rate compared with traditional vaginal repairs [10].

To date, however, the actual adverse event rates and subjective cure rates between different methods of apical repairs remain inconclusive. Adverse events and re-operation rates of mesh versus native tissue-based POP surgeries are inconsistently defined and reported, with limited long-term data. Results from the Colpopexy and Urinary Reduction Efforts (CARE) trial of 233 women receiving primary ASCP estimated a mesh erosion probability of 10.5% at 7 years [5]. The re-operation rate for ASCP has been reported as 4.4% at between 6 months to 3 years [11], and non-mesh vaginal apical repairs such as the USLF and SLS exhibit an estimated surgical failure rate of 61.5 to 70.3% at 5 years [12]. A systematic review comparing mesh sacrocolpopexy against vaginal native tissue apical repairs found no difference in re-operation rates between the two types of procedures; however, significant heterogeneity existed among studies and overall quality of evidence was very low [13]. A Scottish population-based cohort study found no significant differences in re-operation or complications with abdominal or vaginal apical mesh repairs compared with non-mesh vaginal vault repairs [14]. Vaginal vault repairs, however, only comprised a small fraction of the overall patient population. Due to conflicting results, limited prior studies and lack of long-term comparison, further study is warranted.

Our study was designed to determine whether the method of apical POP repair, including mesh use and choice of an abdominal versus vaginal approach, was associated with an increase in repeat POP surgeries. Our secondary objective was to determine whether the mode of vaginal apical POP repair was linked with subsequent fistula repairs, re-operations for 90-day gastrointestinal and genitourinary injuries, and mesh complications requiring surgical removal or extraction.

Materials and methods

Study design and setting

We performed a retrospective, population-based cohort study of all Ontario women who received primary apical repairs for

POP between April 1, 2003, and March 30, 2015. The province of Ontario, Canada, contains approximately 13 million people with universal access to a single health care system. This study was approved by the institutional review board at Sunnybrook Health Sciences Centre, Toronto, Canada. The reporting of this study follows the RECORD (REporting of studies Conducted using Observational Routinely-collected health Data statement) [15] checklist, which incorporates the STROBE guidelines (Appendix 1).

Data sources and validity ascertainment

We obtained our patient population, exposures and covariates using multiple linked databases, including the Canadian Institute for Health Information Discharge Abstract and Same Day Surgery Database (CIHI-DAD/SDS, which captures all inpatient and outpatient procedures in hospital [16]), the Ontario Health Insurance Plan database (OHIP, which captures all health claims for inpatient and outpatient care rendered by physicians [17]), the Institute for Clinical Evaluative Sciences (ICES) Physician Database (IPDB, which contains annual physician demographics, specialization and workload [18]), the National Ambulatory Care Reporting System (NACRS, which captures all emergency department visits [19]), and the Registered Persons Database (RPDB, which contains provincial demographic information [20]). These databases were linked using unique encoded identifiers and analyzed at ICES. Databases are considered complete for all study variables except for physician specialty, which was unknown for 1.7% of relevant physicians. The accuracy, reliability and linkage of these data sets have been previously measured and validated [16–20].

Patient population

We identified all Ontario women who underwent primary mesh-based or native tissue vaginal apical repairs for POP during our study period. The index event was defined as any form of prolapse surgery involving vaginal vault suspension at the time of repair, using synthetic mesh or native tissue. Women were followed up until the first occurrence of a study outcome, death, emigration or end of the observational window (March 31, 2016). We excluded women who had previous mesh or native-tissue based POP surgeries, pelvic radiation, or a history of vesicovaginal, rectovaginal or urethrovaginal fistula before the index date (Supplemental Figure 1). Simple vaginal hysterectomies without concomitant vaginal vault suspensions were not included in our analysis. Previous or concomitant hysterectomy or concurrent anti-incontinence procedures at the time of vaginal vault suspension were allowed.

Outcomes

Our a priori primary outcome was the occurrence of any repeat POP repair (Appendix 3). Repeat POP repairs included mesh-based or native tissue anterior or posterior vaginal repairs, repeat vaginal vault suspensions with or without hysterectomies, and colpocleisis. We only considered the first repeat POP surgery in our analysis. These outcomes were defined using a combination of Canadian Classification of Health Interventions (CCI, from CIHI-DAD/SDS) and OHIP codes.

Our secondary outcomes were subsequent operations for (1) genitourinary and genito-intestinal fistulas any time after the initial repair within the follow-up period; (2) bladder, bowel and ureteric injuries requiring surgical repair within 90 days of the initial apical POP repair; (3) mesh removal, extraction or destruction among the subgroup of women who had mesh-based abdominal or transvaginal apical POP repairs (Appendix 3).

Exposures and covariates

Our primary exposure variable was the type of vaginal apical POP repair, defined using CIHI-DAD/SDS and OHIP coding elements. Patients were categorized into one of four groups: (1) abdominal mesh-based repairs including abdominal, laparoscopic or robotic sacrocolpopexies (SCPs); (2) abdominal native-tissue repairs including Halban and Moschcowitz vaginal suspension procedures or vaginal vault suspension procedures with absorbable sutures; (3) vaginal mesh-based repairs including synthetic transvaginal mesh (TVM) placement; (4) vaginal native-tissue repairs including SSLS, USLF and McCall culdoplasty. Coding definitions for these elements are listed in Appendix 2. To maximize the specificity of apical POP repairs, only CIHI-DAD/SDS coding elements with attached OHIP codes are included in our study. We did not include obliterative POP procedures, isolated anterior and posterior colporrhaphies, uterine preserving suspension procedures and simple hysterectomies to treat POP in our analysis.

We measured 40 clinically relevant covariates including age and socioeconomic status (SES, based on neighborhood income quintiles), medical and surgical comorbidities, health care utilization and surgeon demographics to adjust for factors that potentially influence the choice of vaginal vault POP repair and/or the probability of re-operation (Appendix 4). Perioperative variables including the length of hospital stay, blood transfusion and 90-day ICU admission rates were collected. Patient comorbidities were measured using the Johns Hopkins University Adjusted Case Groups (ACG®) System Version 10 [21, 22], while health care utilization, hospital stay and surgeon characteristics were determined using CIHI-DAD/SDS, OHIP, IPDB and RPDB. We used 5 years of previous administrative data to determine all covariates except for

health care utilization, for which we used 1 year of previous data.

Statistical analysis

Baseline characteristics were summarized using descriptive statistics. Continuous variables were reported as means (standard deviation [SD]), and differences between index event cohorts were determined using a one-way ANOVA. Categorical variables were reported as frequencies (number [percentage]), and differences were determined using a χ^2 test. A test for trend on the number of mesh-based and native-tissue apical POP repairs between fiscal years 2003 to 2014 was carried out using a Cochran-Armitage trend test, where a two-sided p value < 0.05 was considered significant. We used multivariable cause-specific Cox proportional hazard (Cox PH) models to examine the time to first event occurrence for our outcomes of interest. Patients were censored at death, 1 year after the date of last contact or at the end of study date. We reported hazard ratios (HRs) and 95% confidence intervals (CIs) for repeat POP surgeries, fistula repairs, 90-day bladder, bowel and ureteric repairs, and mesh revisions.

A competing risk analysis was also performed for each outcome of interest using the Fine-Gray subdistribution hazard model [23] because of the higher number of patient deaths in the follow-up period. Death is considered as a competing event, which prevents the outcome of interest from occurring. This approach consisted of developing two cause-specific hazard models, one for the outcome of interest, and the other for the competing event, and then combining them according to the cumulative incidence function to create a subdistribution hazard model. Statistical significance was set at $p < 0.05$ based on a two-sided comparison. Assumptions for the Cox PH models were confirmed for all models. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA).

Results

Baseline characteristics

We initially identified 49,339 Ontario women who underwent an apical POP repair between fiscal years 2003 and 2014 and retained 43,458 women who met our study criteria for the final cohort (Supplemental Figure 1). Mean follow-up time among the women who underwent different types of apical repairs ranged between 6.5 (3.41) to 7.14 (3.63) years. Most women ($n = 37,764$ [86.9%]) underwent non-mesh apical repairs for POP through the vaginal approach, with 1187 (2.7%) undergoing abdominal mesh-based repairs, 2179 (5.0%) undergoing abdominal non-mesh repairs and 2328 (5.4%) undergoing vaginal mesh-based repairs. The most relevant details of our

patient cohorts are reported in Table 1, and the full list of baseline characteristics is provided in Appendix 5.

Women receiving any mesh-based apical repairs were slightly older, less likely to reside in a rural area, more likely to have had the operation in a teaching hospital and more likely to have undergone a previous hysterectomy or anti-incontinence procedure. In addition, women receiving mesh-based repairs more likely received prior investigations including urodynamic testing, cystoscopy, postvoid residual measurements and urine cultures. The number of women receiving mesh-based apical POP repairs decreased with time, while

the number of women receiving native-tissue repairs increased slightly (log-rank $p < 0.001$; data not shown).

Compared with women receiving vaginal apical repairs, women undergoing abdominal repairs were slightly younger and more likely to have undergone a previous hysterectomy but less likely to have received a concurrent anterior or posterior repair. Postoperatively, women receiving the abdominal apical POP repair approach had longer hospital stays, higher percentage of blood transfusions and slightly higher ICU admission rates within 90 days. The proportion of repairs performed at teaching hospitals, baseline comorbidity index and

Table 1 Important baseline characteristics of women receiving primary apical POP repairs at index date, classified by surgical approach and mesh use

Patient characteristics ($n = 43,458$)	Mesh-based repair		Native tissue repair		<i>P</i> value
	Abdominal ($n = 1187$)	Vaginal ($n = 2328$)	Abdominal ($n = 2179$)	Vaginal ($n = 37,764$)	
Demographics					
Age, mean (SD), years	62.30 (11.14)	63.37 (11.61)	56.95 (12.90)	60.21 (12.59)	< 0.001
Rural residence (n, %)	204 (17.2%)	280 (12.0%)	330 (15.1%)	6947 (18.4%)	< 0.001
ACG Resource Utilization Band (RUB), median (IQR)	4 (3–4)	4 (3–4)	3 (3–4)	3 (3–4)	< 0.001
Socioeconomic status at lowest quintile (n, %)	190 (16.0%)	310 (13.3%)	377 (17.3%)	6313 (16.7%)	< 0.001
Socioeconomic status at highest quintile (n, %)	251 (21.1%)	590 (25.3%)	431 (19.8%)	7963 (21.1%)	< 0.001
Surgery performed at teaching hospital (yes, %)	531 (44.7%)	1215 (52.2%)	641 (29.4%)	9574 (25.4%)	< 0.001
Charlson Comorbidity Index					
Mean (SD)	0.27 (0.85)	0.31 (0.89)	0.29 (0.88)	0.27 (0.81)	0.278
Comorbidity index ≤ 1 (n, %)	772 (65.0%)	1453 (62.4%)	1319 (60.5%)	22,537 (59.7%)	< 0.001
Follow-up time in years (mean, SD)	7.01 (3.50)	6.79 (3.11)	7.14 (3.63)	6.50 (3.41)	< 0.001
Medical and surgical covariates					
Obesity	11 (0.9%)	26 (1.1%)	31 (1.4%)	472 (1.2%)	0.603
Diabetes	89 (7.5%)	208 (8.9%)	132 (6.1%)	3286 (8.7%)	< 0.001
Previous hysterectomy	220 (18.5%)	222 (9.5%)	139 (6.4%)	2041 (5.4%)	< 0.001
Previous SUI repair	125 (10.5%)	111 (4.8%)	93 (4.3%)	1347 (3.6%)	< 0.001
Previous urodynamic testing	405 (34.1%)	622 (26.7%)	385 (17.7%)	6489 (17.2%)	< 0.001
Previous cystoscopy	358 (30.2%)	544 (23.4%)	387 (17.8%)	6473 (17.1%)	< 0.001
Concurrent anterior and/or posterior repair	824 (69.4%)	1995 (85.7%)	2066 (94.8%)	37,122 (98.3%)	< 0.001
Concurrent hysterectomy	459 (38.7%)	1438 (61.8%)	1694 (77.7%)	29,545 (78.2%)	< 0.001
Concurrent SUI repair	579 (48.8%)	713 (30.6%)	566 (26.0%)	6961 (18.4%)	< 0.001
Surgeon specialty					
Gynecology	1077 (90.7%)	2294 (98.5%)	2093 (96.1%)	37,126 (98.3%)	< 0.001
Urology	84 (7.1%)	25 (1.1%)	41 (1.9%)	335 (0.9%)	
Other	26 (2.2%)	9 (0.4%)	45 (2.1%)	303 (0.8%)	
Blood transfusion within 90 days (yes, %)	38 (3.2%)	42 (1.8%)	79 (3.6%)	719 (1.9%)	< 0.001
ICU admission within 90 days (n, %)	157 (13.2%)	139 (6.0%)	229 (10.5%)	4130 (10.9%)	< 0.001
Length of hospital stay in days (mean, SD)	4.29 (4.14)	2.91 (1.69)	3.88 (2.00)	3.48 (2.13)	< 0.001
Health care utilization within 365 days of index date					
Number of hospitalization for any reason (mean, SD)	0.09 (0.38)	0.09 (0.37)	0.08 (0.35)	0.08 (0.32)	0.132
Number of gynecology visits (mean, SD)	2.34 (1.99)	2.25 (1.82)	2.41 (2.02)	2.20 (1.69)	< 0.001
Number of general practice visits (mean, SD)	7.14 \pm 6.81	7.57 \pm 7.07	6.90 \pm 5.86	6.87 \pm 6.34	< 0.001

health care utilization remained similar between cohorts receiving abdominal versus vaginal repairs.

Primary analysis

The proportion of women receiving repeat POP surgeries in each cohort is shown in Table 2. Covariates including patient age, SES, whether surgery was performed in a teaching hospital and health care utilization were adjusted for in both the cause-specific multivariable Cox PH model and the subdistribution Cox PH analysis accounting for the competing event of death (Table 3). The full list of adjusted covariates in the final models are listed in Appendix 6. Overall, the risk of repeat POP surgery was lower if the initial apical repairs were performed in teaching hospitals, if a concurrent hysterectomy, anterior or posterior compartment repair was done and if the initial procedure was performed by a gynecologist as opposed to a urologist or other surgical specialties. The risk of POP re-operation increased if the patient had received a previous anti-incontinence procedure. Ninety-day mortality was < 0.1% after any method of apical POP repair regardless of mesh use (Appendix 5).

The absolute number of women receiving at least one repeat POP surgery during the follow-up period was 119 [10%] in the abdominal mesh cohort, 202 [9%] in the vaginal mesh cohort, 148 [7%] in the abdominal non-mesh cohort and 2306 [6%] in the vaginal non-mesh cohort. Median time between index surgery and first repeat POP surgery ranged from 1.95 [0.95–4.50] years in the vaginal mesh cohort to 2.55 [1.21–5.31] years in the abdominal non-mesh cohort (Table 2). Unadjusted analysis demonstrated an increased risk of POP re-operation in women who received mesh-based compared with non-mesh-based apical repairs (abdominal mesh group: HR 1.60 [95% CI: 1.33–1.92], $p < 0.001$; vaginal mesh group: HR 1.39 [95% CI: 1.21–1.61], $p < 0.001$; Table 2).

Our multivariable cause-specific analysis again demonstrated a significant increase in the POP re-operation rate in the vaginal mesh cohort compared with the vaginal non-mesh cohort (HR 1.28 [95% CI: 1.10–1.49]; $p = 0.001$). However, the increase in re-operation was no longer significantly elevated for our abdominal mesh cohort in the adjusted model (HR 1.11 [95% CI: 0.91–1.34]; $p = 0.31$). There was no significant increase in the POP re-operation rate in the abdominal non-mesh cohort (HR 0.96 [95% CI: 0.81–1.13]; $p = 0.65$) (Table 2). The subdistribution HRs from our competing risk analysis adjusting for patient deaths were consistent with those of our primary multivariable analysis (Appendix 6).

Secondary analyses

Overall, new onset fistulas and iatrogenic organ injuries were rare after apical prolapse repairs in all cohorts. The number of women receiving surgeries for genitourinary and/or genitointestinal fistulas during the study period ranged from 0 [0%] in the abdominal mesh cohort to 63 [0.2%] in the vaginal non-mesh cohort. The abdominal non-mesh cohort had the highest proportion of fistula repairs at 0.4% (Appendix 7). The number of patients with bladder, bowel and ureteric injuries requiring re-operation within 90 days of the index event remained low in all 4 patient cohorts; ≤ 5 women ($\leq 0.2\%$) in the vaginal mesh cohort, ≤ 5 ($\leq 0.2\%$) in the abdominal non-mesh cohort and 60 (0.16%) in the vaginal non-mesh cohort required a re-operation for possible gastrointestinal (GI) and genitourinary (GU) complications (Appendix 8). No patients in the abdominal mesh cohort had 90-day bladder, bowel or ureteric re-operations. The low event rate for these two secondary outcomes precluded further statistical modeling.

When examining re-operations for mesh removal, revision or extraction in the abdominal mesh and vaginal mesh patient cohorts, 141 women (11.9%) in the abdominal mesh and 266

Table 2 Proportion of women receiving one or more repeat POP surgeries after the index surgery date, with unadjusted and adjusted hazard ratios for each cohort

	Mesh-based repair		Native tissue repair	
	Abdominal (n = 1187)	Vaginal (n = 2328)	Abdominal (n = 2179)	Vaginal (n = 37,764)
Patient years of follow-up	7698.90	14,827.19	14,728.80	233,948.90
Number (proportion) of patients with \geq 1 repeat POP surgery	119 (10.0%)	202 (9.0%)	148 (7.0%)	2306 (6.0%)
Median time in years (IQR) between index surgery date to first repeat POP surgery	2.24 (1.10–4.68)	1.95 (0.948–4.496)	2.55 (1.21–5.31)	2.01 (1.02–4.12)
Event rate per 100 person-years (95% CI)	1.55 (1.28–1.85)	1.36 (1.18–1.56)	1.00 (0.85–1.18)	0.99 (0.95–1.03)
Unadjusted HR (95% CI)	1.60 (1.33–1.92)	1.39 (1.21–1.61)	1.06 (0.90–1.25)	1.00 (reference)
P value for unadjusted HR	<0.0001	<0.0001	0.5159	N/A
Adjusted cause-specific HR for repeat POP operation	1.11 (0.91–1.35)	1.28 (1.10–1.48)	0.96 (0.81–1.13)	1.00 (reference)
P value for adjusted HR	0.30	0.0014	0.62	N/A

Table 3 Important patient and surgical covariates adjusted in the multivariable cause-specific Cox PH model accounting for repeat POP surgeries (cause-specific HR) and in the competing risk Cox PH analysis accounting for both patient deaths and repeat POP surgeries (subdistribution HR)

Adjusted covariate	Cause-specific HR (95% CI) for repeat POP surgeries	<i>P</i> value	Subdistribution HR (95% CI) for deaths and repeat POP surgeries	<i>P</i> value
Patient age (each year increase)	0.99 (0.98–0.99)	< 0.001	0.99 (0.99–0.99)	< 0.001
Rural residence	1.06 (0.95–1.18)	0.29	1.06 (0.95–1.18)	0.29
Highest income quintile	1.18 (1.04–1.33)	0.01	1.19 (1.05–1.34)	0.008
Resource utilization band (each band increase)	0.93 (0.86–1.01)	0.07	0.92 (0.85–1.00)	0.04
Teaching hospital	0.88 (0.80–0.98)	0.02	0.88 (0.80–0.98)	0.01
Diabetes mellitus	0.97 (0.84–1.13)	0.70	0.97 (0.83–1.12)	0.66
Prior hysterectomy	1.01 (0.87–1.17)	0.94	1.01 (0.87–1.17)	0.92
Prior SUI	1.18 (1.00–1.40)	0.06	1.19 (1.00–1.40)	0.05
Prior urodynamic studies	1.29 (1.13–1.47)	< 0.001	1.29 (1.13–1.48)	< 0.001
Prior cystoscopy	1.00 (0.87–1.14)	0.98	1.00 (0.87–1.15)	0.99
Concurrent anterior and posterior repair	0.78 (0.72–0.86)	< 0.001	0.79 (0.72–0.86)	< 0.001
Concurrent hysterectomy	0.71 (0.64–0.78)	< 0.001	0.71 (0.65–0.78)	< 0.001
Concurrent SUI repair	1.22 (1.11–1.34)	< 0.001	1.22 (1.11–1.35)	< 0.001
Urology as primary surgeon (gynecology as reference)	1.75 (1.34–2.30)	< 0.001	1.75 (1.31–2.33)	< 0.001
Number of urology visits	1.00 (0.95–1.05)	0.87	0.99 (0.94–1.05)	0.84
Number of gynecology visits	1.03 (1.01–1.05)	0.01	1.03 (1.00–1.05)	0.02
Number of family medicine visits	1.00 (0.99–1.01)	0.25	1.00 (1.00–1.01)	0.30
Urine culture (yes)	0.99 (0.91–1.08)	0.87	0.99 (0.91–1.08)	0.86
Pelvic ultrasound (yes)	0.86 (0.78–0.94)	0.001	0.85 (0.78–0.94)	0.001
Postvoid residual measurement (yes)	0.91 (0.75–1.11)	0.37	0.91 (0.75–1.11)	0.37

women (11.4%) in the vaginal mesh cohort were classified as having received one or more repeat surgeries for mesh-related complications. Median time [IQR] from initial apical POP repair to first surgery for mesh complications was 1.87 [0.46–4.47] years in patients who received primary abdominal mesh procedures and 2.43 [0.67–4.71] years in patients who received primary vaginal mesh procedures. When the vaginal mesh cohort was used as the reference standard in our multivariable cause-specific analysis (Appendix 9), no difference in re-operation for mesh removal, revision or extraction was seen between the abdominal and vaginal mesh groups (adjusted HR 0.99 [95% CI: 0.78–1.26]; $p = 0.99$).

Discussion

Vaginal apical suspension is increasingly recognized as an essential component of POP repairs; however, the optimal method and route of apical repair remains controversial. In our population-based study comparing various methods of primary apical POP repairs, we found a significant increase in re-operation for recurrent POP in Ontario women receiving transvaginal mesh apical repairs. We detected no significant difference in mesh revision or removal between women receiving abdominal versus transvaginal mesh repairs, with

approximately 12% of women from each group requiring re-operation for mesh removal or revision. Our study is the largest known population-based cohort study to date to compare different methods of vaginal apical POP repairs and to examine the clinically important factors leading to re-operation for failure and complications with each approach.

After adjusting for multiple covariates including surgeon subspecialty, academic versus community hospitals, intraoperative complications and concomitant procedures such as hysterectomy and incontinence surgeries, we found a 39% increase in re-operation risk in women receiving transvaginal mesh apical repairs compared with vaginal native tissue repairs. Although our administrative data sources did not capture preoperative POP-Q scores in our patient cohorts, previous studies have identified similar baseline POP stages between patients receiving mesh and native tissue apical repairs [24, 25]. We also addressed potential disease heterogeneity by adjusting for factors contributing to POP severity including patient age, obesity, hysterectomy and anti-incontinence repair status, and health care utilization. This increase in re-operation for further prolapse surgery post-vaginal mesh placement is consistent with previous literature [14, 26]. However, when abdominal mesh apical suspension (such as SCPs) was compared with vaginal native tissue repairs (such as SSLs or USLF) on multivariable analyses, we detected no

difference in repeat POP surgery between these two groups. Previous smaller studies found equivocal outcomes between these approaches in composite re-operation for complications and surgical failures [13], but longer follow-up data were lacking. Our study therefore suggests that, compared with abdominal repairs for treatment of apical prolapse, primary vaginal native tissue repairs confer an equivalent re-operation rate for surgical failure.

The risk of re-operation for repeat POP was lower when the initial apical repair was done in teaching hospitals, when performed with a concurrent hysterectomy or other vaginal repairs, and when a gynecologist was the primary surgeon. While vaginal apical suspension is considered superior to simple anterior or posterior repairs alone, the majority of vaginal prolapses are still managed with isolated anterior or posterior repairs [27]. When surgeon expertise was examined in the context of transvaginal prolapse mesh, surgeons performing 14 or more transvaginal mesh placements yearly had the lowest rate of mesh re-operation [28]. The Society of Obstetricians and Gynecologists Canada (SOGC) also supports the need for additional training and mentorship prior to performing transvaginal mesh procedures [26]. Our findings are consistent with previous literature advocating for increased surgeon training in performing POP surgeries, with surgeon expertise incorporated in covariates at the hospital, procedural and surgeon levels. It is reassuring, however, that 90-day GI and GU complications remain rare regardless of mesh use or initial surgical approach.

When mesh use in vaginal apical repairs was examined separately, we again noted no difference in mesh removal, revision or excision between abdominal mesh and transvaginal mesh apical POP repairs on multivariable analysis. Our mesh complication rates were similar for abdominal and vaginal mesh, consistent with literature reporting SCP mesh extrusion rates of 10.5% [5] and transvaginal mesh exposure rates of 12.2% [26]. Specifically, we noted a similar long-term mesh revision and excision rate between primary abdominal and vaginal mesh procedures after adjusting for patient, surgeon and intraoperative covariates, contrary to previous studies suggesting a higher mesh complication rate with transvaginal mesh kits [29]. This lack of difference may be partly explained by our long follow-up time. In addition, mesh SCPs are most often performed by trained urogynecologists in academic hospitals, and patients in the abdominal mesh cohort may therefore be subject to a closer follow-up and lower threshold for detection of mesh complications. However, it is evident that approximately one in ten women will receive mesh revisions or removal in their lifetime if mesh is used during the primary apical suspension procedure, regardless of the mode of mesh placement.

Our study has several strengths. One strength is the long follow-up period post initial apical POP repair (mean follow-up of 6.5 to 7.14 years). Previous smaller studies examining re-operation and complication rates post apical POP repair report

an average of 1–3 years of follow-up [13, 29], with the longest mean follow-up recorded at 5 years in a Scottish population-based cohort study [14]. Additionally, the validity and generalizability of our study results, encompassing all women in Ontario, Canada, during the study period, are increased given the wide variety of surgeons and patients at both teaching and community hospitals. This population-based study is the largest to date to capture all methods and approaches of vaginal apical repairs in women undergoing primary POP surgeries. We linked multiple validated databases and examined 40 patient and surgical covariates to maximize balance between patient cohorts. We also acknowledge several study limitations. All observational studies may have differential misclassification of study covariates and residual confounding, such as potential heterogeneity in POP stage at baseline. Although we attempted to adjust for surgeon expertise through surgeon subspecialty training and region, gynecologists with subspecialty training in urogynecology are not consistently differentiated from general gynecologists with our databases. In addition, surgeons at academic centers possibly had a lower threshold to re-operate on any type of mesh complication, which may explain the lack of difference between the abdominal mesh and vaginal mesh cohorts for mesh revision or removal. Women in the vaginal mesh group also had a longer interval between initial apical repair and first re-operation for mesh complications, which may be secondary to the wait time to subspecialist referral since it is recommended that a female pelvic reconstructive surgeon with appropriate training be referred to for mesh complications related to vaginal prolapse surgeries [30].

Conclusions

Among women receiving primary apical suspension procedures for POP, the risk of re-operation for recurrent POP is increased for transvaginal mesh repairs compared with abdominal mesh repairs or any method of native tissue repair. However, the risk of re-operation for recurrent POP did not differ between abdominal mesh and vaginal native tissue repairs. Genital fistulas and 90-day GI and GU complications were rare regardless of mesh use or approach of apical repair. We found no difference in mesh removal or revision between abdominal mesh and transvaginal mesh groups; however, when mesh is placed by either approach during a primary apical suspension procedure, approximately one in ten women will require mesh removal or revision in their lifetime. Our results suggest that vaginal native-tissue apical repairs are as effective as abdominal mesh repairs when repeat POP surgery is used as a marker for objective success, without the risk of subsequent mesh revisions. In the context of the existing mesh controversy in prolapse repairs, these findings further highlight the careful selection and counseling of patients prior to any mesh placement for vaginal apical suspension.

Acknowledgements The opinions, results and conclusions are those of the authors and are independent from the funding sources. No endorsement by the LHSC Women's Development Council, ICES, AMOSO, SSMD, LHRI or MOHLTC is intended or should be inferred. This research project was conducted in collaboration with members of the ICES Kidney, Dialysis and Transplantation team, at the ICES Western facility, who are supported by a grant from the Canadian Institutes of Health Research (CIHR).

Parts of this material are based on data and/or information compiled and provided by CIHI. However, the analyses, conclusions, opinions and statements expressed in the material are those of the author(s) and not necessarily those of CIHI.

Disclosure of financial support This study was funded by the Women's Development Council at London Health Sciences Centre (LHSC), London Ontario, Canada. The Women's Development Council is funded in part by donors of the London Health Sciences Foundation (LHSF) and by the Department of Obstetrics and Gynecology at LHSC. This study was supported by the Institute for Clinical Evaluative Sciences (ICES) Western site, which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care (MOHLTC). Core funding for ICES Western is provided by the Academic Medical Organization of Southwestern Ontario (AMOSO), the Schulich School of Medicine and Dentistry (SSMD), Western University and the Lawson Health Research Institute (LHRI).

Compliance with ethical standards

Conflicts of interest None.

References

- Jelovsek JE, Maher C, Barber MD. Pelvic organ prolapse. *Lancet*. 2007;369(9566):1027–38.
- Shull BL. Pelvic organ prolapse: anterior, superior, and posterior vaginal segment defects. *Am J Obstet Gynecol*. 1999;181(1):6–11.
- Alas AN, Anger JT. Role of apical support defect: correction in women undergoing vaginal prolapse surgery. *Curr Opin Obstet Gynecol*. 2014;26(5):386–92.
- Raman SV, Raker CA, Sung VW. Concomitant apical prolapse repair and incontinence procedures: trends from 2001–2009 in the United States. *Am J Obstet Gynecol*. 2014;211(3):222.e1–5.
- Nygaard I, et al. Long-term outcomes following abdominal sacrocolpopexy for pelvic organ prolapse. *Jama*. 2013;309(19):2016–24.
- Dubuisson J, et al. Laparoscopic repair of vaginal vault prolapse by lateral suspension with mesh. *Arch Gynecol Obstet*. 2013;287(2):307–12.
- Younger A, et al. Pelvic organ prolapse surgery in academic female pelvic medicine and reconstructive surgery urology practice in the setting of the Food and Drug Administration public health notifications. *Urology*. 2016;91:46–50.
- Administration, U.F.a.D. Urogynecologic surgical mesh: update on the safety and effectiveness of transvaginal placement for pelvic organ prolapse. Center for Devices and Radiological Health; 2011. p. 15.
- Feiner B, Maher C. Vaginal mesh contraction: definition, clinical presentation, and management. *Obstet Gynecol*. 2010;115(2 Pt 1):325–30.
- Iglesia CB, et al. Vaginal mesh for prolapse: a randomized controlled trial. *Obstet Gynecol*. 2010;116(2 Pt 1):293–303.
- Nygaard IE, et al. Abdominal sacrocolpopexy: a comprehensive review. *Obstet Gynecol*. 2004;104(4):805–23.
- Jelovsek JE, et al. Effect of uterosacral ligament suspension vs sacrospinous ligament fixation with or without perioperative behavioral therapy for pelvic organ vaginal prolapse on surgical outcomes and prolapse symptoms at 5 years in the OPTIMAL randomized clinical trial. *Jama*. 2018;319(15):1554–65.
- Siddiqui NY, et al. Mesh sacrocolpopexy compared with native tissue vaginal repair: a systematic review and meta-analysis. *Obstet Gynecol*. 2015;125(1):44–55.
- Morling JR, et al. Adverse events after first, single, mesh and non-mesh surgical procedures for stress urinary incontinence and pelvic organ prolapse in Scotland, 1997–2016: a population-based cohort study. *Lancet*. 2017;389(10069):629–40.
- Benchimol EI, et al. The REporting of studies conducted using observational routinely-collected health data (RECORD) statement. *PLoS Med*. 2015;12(10):e1001885.
- Williams J, Young W. Appendix I: a summary of studies on the quality of health care administrative databases in Canada. In: Williams J, Goel V, Anderson GM et al., editors. *Patterns of Health Care in Ontario: the ICES Practice Atlas*, 2nd edition. Canadian Medical Association; 2000. p. 339–347.
- Raina P, et al. Agreement between self-reported and routinely collected health-care utilization data among seniors. *Health Serv Res*. 2002;37(3):751–74.
- Iron K, Manuel D. Quality assessment of administrative data (QuAAD): an opportunity for enhancing Ontario's health data. ICES investigative report. Toronto: Institute for Clinical Evaluative Sciences; 2007.
- Gibson D, Richards H, Chapman A. The National Ambulatory Care Reporting System: factors that affect the quality of its emergency data. *Int J Inf Qual*. 2008;2(2):97–114.
- Jha P, et al. Characteristics and mortality outcomes of thrombolysis trial participants and nonparticipants: a population-based comparison. *J Am Coll Cardiol*. 1996;27(6):1335–42.
- Weiner JP. The Johns Hopkins ACG® Case-Mix System Version 10.0 Release Notes., H.S.R.D.C. The Johns Hopkins University Bloomberg School of Public Health, Editor. 2011: The Johns Hopkins University.
- Austin PC, et al. Using the Johns Hopkins aggregated diagnosis groups (ADGs) to predict mortality in a general adult population cohort in Ontario, Canada. *Med Care*. 2011;49(10):932–9.
- Fine JP, Gray RJ. A proportional hazards model for the subdistribution of a competing risk. *J Am Stat Assoc*. 1999;94(446):496–509.
- LO T-S, WANG AC. Abdominal Colposacropexy and sacrospinous ligament suspension for severe Uterovaginal prolapse: a comparison. *J Gynecol Surg*. 1998;14(2):59–64.
- Chen Y, Hua K. Medium-term outcomes of laparoscopic sacrocolpopexy or sacrohysteropexy versus vaginal sacrospinous ligament fixation for middle compartment prolapse. *Int J Gynaecol Obstet*. 2017;137(2):164–9.
- Larouche M, Geoffrion R, Walter J-E. No. 351-transvaginal mesh procedures for pelvic organ prolapse. *J Obstet Gynaecol Can*. 2017;39(11):1085–97.
- Stewart JR, Hamner JJ, Heit MH. Thirty years of cystocele/rectocele repair in the United States. *Female Pelvic Med Reconstr Surg*. 2016;22(4):243–7.
- Kelly EC, Winick-Ng J, Welk B. Surgeon experience and complications of transvaginal prolapse mesh. *Obstet Gynecol*. 2016;128(1):65–72.
- Diwadkar GB, et al. Complication and reoperation rates after apical vaginal prolapse surgical repair: a systematic review. *Obstet Gynecol*. 2009;113(2 Pt 1):367–73.
- Committee Opinion No. 694: Management of Mesh and Graft Complications in gynecologic surgery. *Obstet Gynecol*. 2017;129(4):e102–e108.