World Journal of Urology
https://doi.org/10.1007/s00345-018-2541-y

ORIGINAL ARTICLE

Bladder and ureteral injuries during benign hysterectomy: an observational cohort analysis in New York State

Cooper R. Benson[1] · Stephanie Thompson[1] · Gen Li[2] · Denise Asafu-Adjei[1] · Steven B. Brandes[1]

Received: 9 July 2018 / Accepted: 20 October 2018

Abstract

Purpose Hysterectomy (Hys) is the most common non-urologic surgery associated with iatrogenic genitourinary (GU) injury. We present the largest known population-based evaluation of GU injury related to benign Hys.

Methods The New York Statewide Planning and Research Cooperative System (SPARCS) was queried by ICD-9 and CPT codes. SPARCS for women from 1995 to 2014, who underwent laparoscopic or robotic Hys (minimally invasive surgery = MIS), abdominal Hys (AH), and vaginal Hys (VH) for benign diagnoses. Bladder and ureteral repairs were captured based on the procedure codes. Codes for ureteroneocystotomy (UNC) were compared to any other ureteral repairs, to elucidate injury patterns. Statistical analysis was conducted using Chi squared test, ANOVA, Mann–Whitney test and Poisson Regression and multivariable analysis were performed.

Results 516,340 women underwent Hys for a benign etiology. 69% were AH, 25% VH, and 6% were MIS. 7490 patients (1.45%) had a concomitant GU injury. Compared to VH, MIS and AH were associated with greater odds of bladder and ureteral injury ($p < 0.001$). MIS and AH, compared to VH, were associated with reduced odds of UNC compared to complex reconstruction (OR 0.27, $p < 0.001$ and OR 0.12, $p < 0.00$, respectively). The injured cohort had higher total mean charges ($29,889 vs $15,808) and length of hospitalization (6.32 vs 3.56 days) ($p < 0.001$).

Conclusions Bladder and ureteral injuries during hysterectomy are uncommon in contemporary practice and are lower than historical rates. GU injury increases hospitalization cost. VH is associated with the lowest rate of GU injury, and thus appears to be a valuable approach, when feasible.

Keywords Hysterectomy · Bladder injury · Ureteral injury · Population analysis

Introduction

Gynecologic surgery, hysterectomy in particular, represents the most common source of non-urologic iatrogenic genitourinary (GU) injury. There are an estimated 600,000 hysterectomies performed annually in the United States [1, 2]. Iatrogenic GU injury during hysterectomy has potential for significant morbidity including delayed convalescence, the need for secondary procedures, as well as increasing health care costs. A population analysis examining factors associated with bladder injury (BI), utilizing the National Surgical Quality Improvement Program (NSQIP) database, found that 30% of iatrogenic BI were associated with gynecologic surgery [3].

The incidence of ureteral injury (UI) during gynecologic surgery ranges 0.083–2.5% in published literature, and is often more common during oncologic surgery [3–6]. The most common sites of ureteral injury are at the infundibulopelvic ligament, the distal uterosacral ligament (as the ureter courses under the uterine artery near the cardinal ligament), and near the cervix and vaginal cuff in the proximity of the ureterovesical junction [4, 5, 7].

There are multiple potential mechanisms of BI and UI; this includes contusion, thermal injury, laceration of bladder or ureter, ureteral transection, ureteral ligation or kinking,

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00345-018-2541-y) contains supplementary material, which is available to authorized users.

✉ Steven B. Brandes
Sbb2169@cumc.columbia.edu

[1] Department of Urology, Columbia University Medical Center, 161 Ft. Washington Ave 11th Floor, New York, NY 10032, USA

[2] Department of Biostatistics, Columbia University Medical Center, New York, NY, USA

Published online: 07 November 2018

and devascularization of the ureter [4]. A delayed diagnosis of UI increases the risk of complications including infection, pain, urinoma, hydronephrosis, renal injury or renal loss and can thus result in increased health care costs [6, 8]. Furthermore, GU injury during benign gynecologic surgery has also been associated with impaired quality of life, disability, as well as litigation [9].

There are multiple surgical approaches, at the discretion of the surgeon, to remove the uterus for non-malignant diagnoses. While traditional open abdominal hysterectomy (AH) clearly has a role in benign hysterectomy, there is a push for minimally invasive surgical approaches to hysterectomy; these include vaginal hysterectomy (VH), laparoscopic-assisted vaginal hysterectomy (LAVH), and robotic-assisted hysterectomy.

We sought to examine the trends in GU injury in patients undergoing benign hysterectomy, in a contemporary cohort-based population analysis by differing surgical approaches. We also characterized risk factors for BI and UI during different hysterectomy techniques and to assess the impact of hospitalization and costs related to GU injury. To our knowledge, this is the largest and most contemporary population-based observational cohort analysis of GU injuries associated with benign hysterectomy.

Materials and methods

Data source and population

We queried the New York Statewide Panning and Research Cooperative System (SPARCS) database to identify adult (age ≥ 18 years) women who underwent hysterectomy for benign diagnoses between 1995 and 2014. The SPARCS database is a large comprehensive all payer database reporting system in New York State which collects patient level details on characteristics, diagnoses, treatments, services and charges in both the inpatient and outpatient settings. Each patient is assigned a unique identifier which allows for longitudinal follow-up. Institutional review board exemption status was given due to de-identified data and the retrospective, descriptive design of our study.

Utilizing ICD-9 diagnosis and procedures codes, we identified all women, age ≥ 18 years, who underwent hysterectomy. The SPARCS database reports inpatient procedures using ICD-9-CM codes rather than current procedural terminology (CPT) codes. Women who underwent a hysterectomy for malignancy were excluded from our analysis (Online Resource Table 1). Hysterectomy procedures were further classified by surgical approach: open abdominal hysterectomy (AH), vaginal hysterectomy (VH) and minimally invasive hysterectomy (MIS), which includes laparoscopic or robotic approaches (Online Resource, Table 2). Patients who sustained BI or UI during hysterectomy were identified by ICD-9-CM codes, indicating repair/reconstruction (Online Resource, Table 3). We excluded cystoscopy and ureteral stent placement without coincident bladder and/or ureteral repair codes, due to the inability to distinguish routine pre-operative placement of ureteral stents from stents placed in the setting of ureteral injury during hysterectomy.

The incidence and trends of BI and/or UI related to benign hysterectomy were categorized by surgical approach and risk factors associated with BI and/or UI were identified. The incidence and predictors of UI repair were compared by categorizing UI repairs into "simple" ureteroneocystotomy (ICD-9-CM 56.74) versus more "complex" repairs (i.e. boari flap, uretero-ureterostomy, transuretero-ureterostomy), due to the lack of coding granularity. The repair type was used as a surrogate to define the location of ureteral injury, because the dataset lacked the location and type of ureteral injury information. Additionally, cost analysis was performed comparing women who sustained BI and/or UI to those who had no GU complication related to their hysterectomy.

Statistical analysis

Statistical analysis was performed using *R* statistical software (University of Auckland, New Zealand). Student *t* test was employed for continuous variables, Chi square for nominal categorical variables, and Poisson Regression analysis to characterize hysterectomy and injury trends over time. Multivariable logistic regression analysis were performed to determine risk factors for GU injury. Length of stay and cost analysis was done using one-way ANOVA and Mann–Whitney *U* tests. p value < 0.05 was considered statistically significant.

Results

516,340 women with benign disease had a hysterectomy in New York State between 1995 and 2014. 7490 unique women (1.45%) who had BI and/or UI repaired at the time of surgery or post-operatively were identified. The incidence and distribution of injuries were 0.74% BI, 0.23% UI and 0.02% BI and UI. Interestingly, only 27 patients with GU injury had repeated hospitalizations for urologic repair, indicating the majority (99.6%) were detected on initial hospitalization. Baseline demographic and comorbidity data for the entire cohort and the injured-cohort are detailed in Online Resource 4 and 5. The mean age was 50.16 years. Multivariable analysis was conducted and showed diabetes (OR 0.84, $p < 0.001$), hypertension (OR 0.84, $p < 0.001$), and obesity (OR 0.082, $p = 0.028$) were associated with reduced odds for BI and/or UI, while smoking was associated with an increased odds ($p = 0.002$) (Online Resource Table 6).

Over our 20-year study period, rates of AH and VH decreased over time, while rates of MIS hysterectomy increased (Fig. 1a). Overall rates of each hysterectomy technique were 69% AH, 25% VH and 6% MIS hysterectomy. AH had the longest mean length of stay at 6.54 days compared to 2.91 days for MIS and 3.43 days for VH ($p < 0.001$) (Online Resource Table 5). Figure 1a illustrates that the trends in bladder and ureteral injury repairs during benign hysterectomy remained relatively stable from 1995–2014.

GU injury trends by surgical approach were evaluated over time using regression analyses. Figure 1b (left graph) demonstrates that during AH over the study period, there was a decreasing rate of BI and increasing no GU injury rate (both $p = 0.04$), particularly after 2010. There was an increasing incidence of no injuries ($p < 0.01$) while bladder only injury proportions decreased ($p < 0.01$), also mainly after 2010. (Figure 1b, middle graph). MIS hysterectomy also demonstrated a decreasing incidence of BI ($p = 0.03$), but in sharp contrast to VH and AH, an increasing trend in UI ($p < 0.01$). (Figure 1b, right graph).

Compared to VH, the odds of BI were highest for MIS hysterectomy (OR 3.05 $p < 0.001$) and slightly increased risk for AH (OR 1.19, $p < 0.001$). There were significantly lower odds of ureteral injury in VH compared to AH (OR 11.98, $p < 0.001$) and MIS (OR 12.35, $p < 0.001$) (Table 7, Online Resource). There was a significant difference between the three hysterectomy techniques overall in terms of the rate of "simple" ureteroneocystotomy compared to more complex repairs ($p = 0.042$). Compared to VH, MIS (OR 0.27 $p < 0.001$) and AH (OR 0.13, $p < 0.001$) were much less likely to be associated with ureteroneocystotomy, indicating AH and MIS hysterectomies were associated with more proximal injuries, and thus probably more complex reconstruction (Online Resource Table 8).

There was a significantly increased mean length of hospitalization (6.32 vs 3.56 days) and higher total mean charges ($29,889 vs $15,808) for the injured cohort compared to non-injured patients ($p < 0.001$). The total additional economic burden, based on the charges, for GU injuries during hysterectomy in NYS was $62.6 million over the study period.

Discussion

Our population analysis is similar to prior historical reports on BI and UI during benign hysterectomy. The ranges of BI and UI in the literature of 0.2–1.8% for BI and 0.03–1.5% for UI are consistent with our findings of 0.74% and 0.23% respectively. [5, 8, 10] Three population-based analyses of the NSQIP database on gynecologic and pelvic surgery have similar findings, with 0.36% BI and 0.3% UI [3, 11, 12].

Over our 20-year study period, the rates of BI and UI remained relatively stable. However, the surgical methods selected for hysterectomy gradually shifted, particularly since 2005. In 2005, the FDA approved the utilization of the da Vinci® robotic platform for use in gynecologic surgery [13]. Since that time, there is an significant increase in the utilization of MIS hysterectomy. Pitter et al. found that from 2010 to 2013, there was more than double the number of robotic-hysterectomies from 17% in 2010 to 36% in 2013 with a concomitant decrease in the number of AH [14]. Furthermore, we can expect that the traction of MIS/robotic hysterectomy for benign hysterectomy will continue to increase if the trends persist, and proportionally so will UI, which are potentially more complex to repair. Despite this, the American College of Obstetricians and Gynecologists recommends VH, the original minimally invasive natural orifice surgery, as the preferred surgical approach for benign hysterectomy, when feasible, due to its safety with respect to GU injury [15].

Based on our data, VH has the lowest risk of BI and UI overall relative to other surgical approaches. Our population analysis reveals changes in GU injury rates beginning in 2010. After 2010, there are increasing rates of absent injury and decreasing rates of BI in both AH and VH. Possible explanations for these trends are improved patient selection or a heightened awareness of the GU injury. However, while the relative pressure on physicians to apply new technology in their practice is difficult to measure, the market share of robotic surgery for gynecologic applications certainly continues to rise [14].

In a recent Cochrane review, Aarts et al. also found that MIS hysterectomy had a higher risk of GU injury (BI and UI combined) compared to AH (OR 2.44, 95% CI 1.24–4.80) [16]. They concluded that no difference in GU injury could be appreciated comparing VH to MIS and VH to AH, due to the low number of events in the included studies [16]. Despite this, the authors concluded that VH should be favored over AH and MIS when possible based on superior recovery and return to normal activities [15–17]. Population-based analysis using the NSQIP database also find higher rates of GU injury with MIS [11, 12]. Packiam et al. found similar results and similar highest rates of injury in MIS hysterectomy (0.48%) and lowest for VH (0.04%) [11]. In another NSQIP study, AH was found to have the highest rates of BI repairs and MIS hysterectomy was associated with highest rates of UI repairs and VH had lowest rate of UI overall [12]. Moreover, there was an increasing trend in UI from 0.19% in 2010 to 0.47% in 2014 ($p < 0.001$) [12]. Wong et al. found that rates of GU injury during benign laparoscopic gynecologic surgery to be 0.33%, 0.08% for UI and 0.24% for BI.[18] Mamik et al. found that MIS approach was a significant predictor of UI during benign hysterectomy (OR 10.4, 95% CI 2.3–46.6)

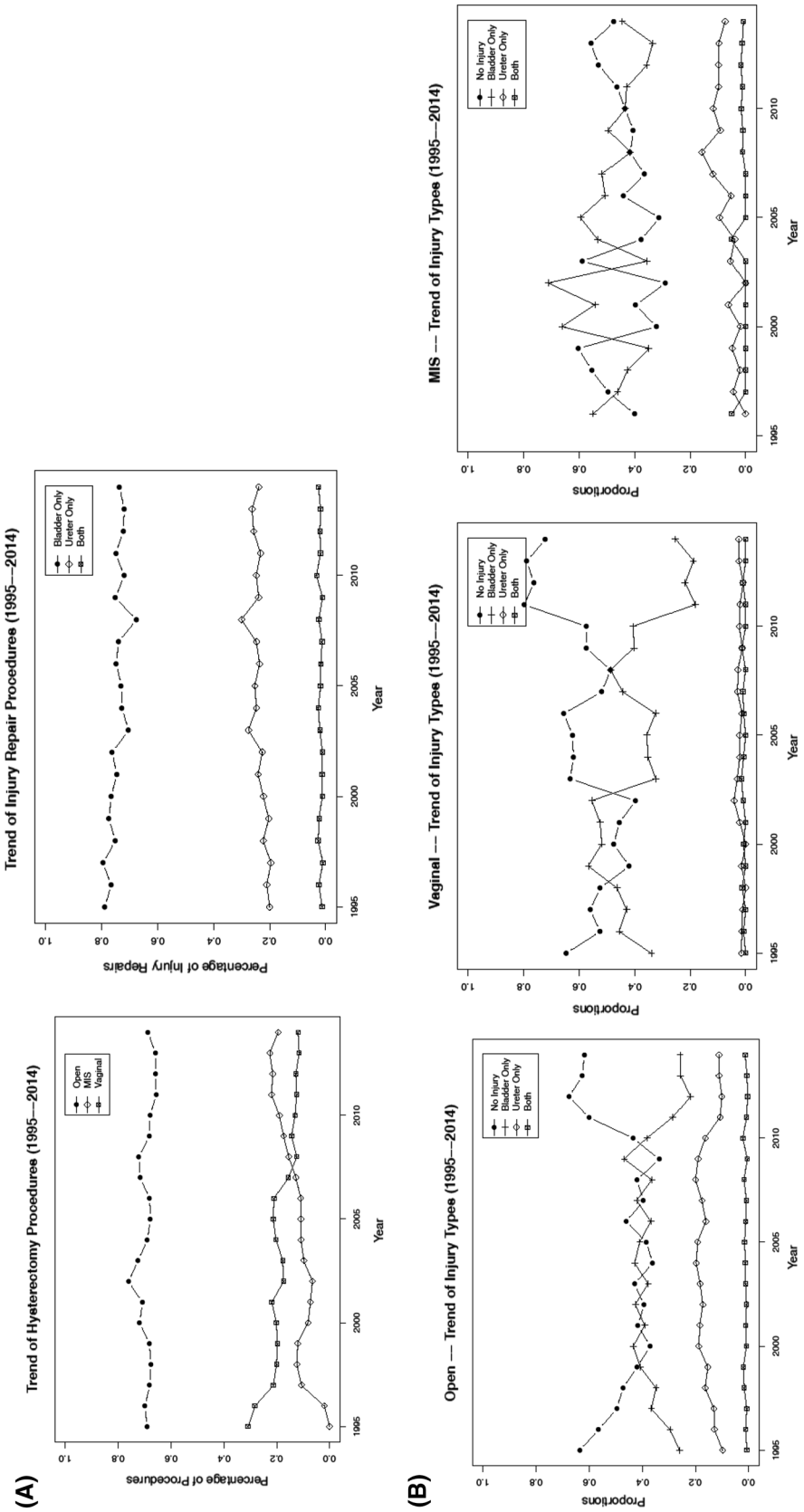

Fig. 1 **a** Left: trends in hysterectomy surgical techniques for benign indications over time in New York State, for benign pathology. Right: trends in types of genitourinary injury over time in New York State. **b** Left: open abdominal hysterectomy related GU Injury Trends. Middle: vaginal hysterectomy related GU Injury Trends. Right: MIS (Laparoscopic/Robotic) Hysterectomy related GU Injury Trends

[19] Consistent among the prior studies is the association between MIS hysterectomy and UI.

Despite the multitude of evidence demonstrating relative increased risk of GU injury during MIS hysterectomy, laparoscopic-and robotic-assisted surgery continues to grow. We identified a rising trend in MIS hysterectomy and decreasing rate of VH for benign pathology. Robotic surgery continues to rise in market-share across multiple surgical subspecialties, and there is untapped potential in gynecology, where there is only 40% utilization.[14]. This is in contradistinction to radical prostatectomies, where robotic surgery utilization is almost at a maximum. There are widespread marketing campaigns advertising robotic-gynecologic surgery, with incomplete information regarding complications, operative time and cost [20]. All the while, VH, in the appropriately selected patient, is an excellent and safe option with respect to GU injury. This begs the question, will iatrogenic injury continue to rise along with the increasing utilization of MIS hysterectomy or will it plateau once the learning curve has been achieved?

In addition to the surgical approach, there are other factors associated with BI and UI during hysterectomy. Several studies have found that higher American Society of Anesthesiologists (ASA) physical classification, increased blood loss, increased length of surgery, large uterus size > 250 g, endometriosis, pelvic adhesions and African American race are associated with increased risk of GU injury [5, 15, 18, 19, 21, 22]. Additionally, prior cesarean section, surgery performed by a generalist gynecologist and concurrent bowel injury were associated with the increased risk of BI, whereas UI was associated with increased blood loss, concurrent bowel injury, and prior pelvic surgery [19].

The location of ureteral injury relative to surgical technique is incompletely characterized in the literature. In our analysis, we found that compared to other approaches, VH was most likely associated with ureteroneocystotomy, and thus more distal ureteral injuries. Ibeanu et al. characterized the locations of ureteral injury, the most common location of injury was at the level of the uterine artery (12/15), two were at the pelvic brim and one at the uterosacral ligament [5]. A possible explanation for the difference in ureteral reconstruction techniques, is that AH and MIS hysterectomy techniques including dissecting more cephalad in the pelvis, putting the more proximal ureter at risk, compared to the distal ureter during VH. Repairing such an injury would be more "complex" than a straightforward ureteroneocystotomy.

There are several limitations of our analysis, outside of the inherent bias associated with retrospective studies. The SPARCS database is subject to coding errors which may have impacted our analysis, the database uses ICD-9-CM procedure codes, rather than CPT codes, and are less descriptive which limited the analysis, especially as it pertains to ureteral reconstruction. There is inherent selection bias with respect to low rates of injury in the VH cohort, given this approach is often utilized for small size uteri and in those patients with less complicated surgical history [23]. Our study likely underestimates the incidence of UI, since we excluded cystoscopy and ureteral stent placement as a procedure of interest and thus likely missed less significant injuries that were just managed with ureteral stent placement. The database is limited in that each admission is a single event and it is impossible to determine whether the BI and UI were recognized and repaired intraoperatively at the time of hysterectomy or a delayed recognition during the same hospitalization. Furthermore, our cost analysis is unadjusted for inflation over the 20-year study period and likely underestimates the difference in costs between the injured and non-injured patients. Our analysis is also limited by the lack of long term follow-up and capturing readmissions.

The strengths of our analysis include the large number of patients undergoing hysterectomy for benign diagnoses and a robust analysis examining the trends and incidence of major bladder and/or ureteral injuries. While BI and/or UI related to benign hysterectomy is infrequent, the impact on patients and the health care system are not miniscule. Future study should differentiate patients who underwent routine ureteral stent placement for intraoperative ureteral identification from those who had stents placed for the minor UI to the better estimate UI risk during benign hysterectomy.

Conclusion

We characterized a large population-based analysis of GU injury related to the elective hysterectomy for benign indications. VH, with respect to rates of GU injury, appears to be the safest approach for benign hysterectomy when feasible. While the risk of BI and UI related to surgical management of benign gynecologic diseases is very low, there is a potentially significant morbidity related to these injuries with increasing lengths of hospitalization and associated costs to the health care system.

Author contributions CRB protocol/project development, manuscript writing. ST data collection and management. GL data analysis. DA-A data collection and management. SBB protocol/project development, manuscript editing.

Compliance with ethical standards

Conflict of interest Gen Li was partially supported by the AIS Investments AIGI CU15-2834. The authors declare that they have no conflict of interest.

Ethical approval For this type of study formal consent is not required. This article does not contain any studies with human participants performed by any of the authors, now does it contain any studies with animals performed by any of the authors.

Informed consent No informed consent from the authors was required by any of the patients included in the analysis due to the de-identified nature of this population database analysis. IRB approval was obtained from Columbia University Medical Center.

References

1. LR SRAD (2012) Upper urinary tract trauma, in campbell-walsh urology. In: Wein AJ (Ed). Elsevier, p. 1169–1189
2. Cordon BH, Fracchia JA, Armenakas NA (2014) Iatrogenic non-endoscopic bladder injuries over 24 years: 127 cases at a single institution. Urology 84(1):222–226
3. Cohen AJ et al (2016) Iatrogenic bladder injury: national analysis of 30-day outcomes. Urology 97:250–256
4. Sharp HT, Adelman MR (2016) Prevention, recognition, and management of urologic injuries during gynecologic surgery. Obstet Gynecol 127(6):1085–1096
5. Ibeanu OA et al (2009) Urinary tract injury during hysterectomy based on universal cystoscopy. Obstet Gynecol 113(1):6–10
6. Schimpf MO, Gottenger EE, Wagner JR (2008) Universal ureteral stent placement at hysterectomy to identify ureteral injury: a decision analysis. BJOG 115(9):1151–1158
7. Esparaz AM et al (2015) Iatrogenic urinary tract injuries: etiology, diagnosis, and management. Semin Intervent Radiol 32(2):195–208
8. Teeluckdharry B, Gilmour D, Flowerdew G (2015) Urinary tract injury at benign gynecologic surgery and the role of cystoscopy: a systematic review and meta-analysis. Obstet Gynecol 126(6):1161–1169
9. Gilmour DT, Baskett TF (2005) Disability and litigation from urinary tract injuries at benign gynecologic surgery in Canada. Obstet Gynecol 105(1):109–114
10. Petersen SS et al (2018) Rate of urologic injury with robotic hysterectomy. J Minim Invasive Gynecol 25(5):867–871
11. Packiam VT et al (2016) The impact of minimally invasive surgery on major iatrogenic ureteral injury and subsequent ureteral repair during hysterectomy: a national analysis of risk factors and outcomes. Urology 98:183–188
12. Wallis CJ et al (2016) Occurrence of and risk factors for urological intervention during benign hysterectomy: analysis of the national surgical quality improvement program database. Urology 97:66–72
13. Bouquet de Joliniere J et al (2016) Robotic surgery in gynecology. Front Surg 3:26
14. Pitter MC et al (2014) The impact of different surgical modalities for hysterectomy on satisfaction and patient reported outcomes. Interact J Med Res 3(3):e11
15. ACOG Committee Opinion. Number 372. July 2007 (2007) The Role of cystourethroscopy in the generalist obstetrician-gynecologist practice. Obstet Gynecol 110(1):221–224
16. Aarts JW et al (2015) Surgical approach to hysterectomy for benign gynaecological disease. Cochrane Database Syst Rev 12(8):1–132
17. David-Montefiore E et al (2007) Surgical routes and complications of hysterectomy for benign disorders: a prospective observational study in French university hospitals. Hum Reprod 22(1):260–265
18. Wong JMK et al (2018) Urinary tract injury in gynecologic laparoscopy for benign indication: a systematic review. Obstet Gynecol 131(1):100–108
19. Mamik MM et al (2014) Risk factors for lower urinary tract injury at the time of hysterectomy for benign reasons. Int Urogynecol J 25(8):1031–1036
20. Schiavone MB et al (2012) The commercialization of robotic surgery: unsubstantiated marketing of gynecologic surgery by hospitals. Am J Obstet Gynecol 207(3):174.e1–174.e7
21. Satitniramai S, Manonai J (2017) Urologic injuries during gynecologic surgery, a 10-year review. J Obstet Gynaecol Res 43(3):557–563
22. Anand M et al (2015) Utility of intraoperative cystoscopy in detecting ureteral injury during vaginal hysterectomy. Female Pelvic Med Reconstr Surg 21(2):70–76
23. Committee Opinion No 701 (2017) Choosing the route of hysterectomy for benign disease. Obstet Gynecol 129(6):e155–e159