GYNECOLOGY

Cystoscopy at the time of benign hysterectomy: a decision analysis

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BACKGROUND: Gynecologists debate the optimal use for intraoperative cystoscopy at the time of benign hysterectomy. Although adding cystoscopy leads to additional up-front cost, it may also enable intraoperative detection of a urinary tract injury that may otherwise go unnoticed. Prompt injury detection and intraoperative repair decreases morbidity and is less costly than postoperative diagnosis and treatment. Because urinary tract injury is rare and not easily studied in a prospective fashion, decision analysis provides a method for evaluating the cost associated with varying strategies for use of cystoscopy.

OBJECTIVE: The objective of the study was to quantify costs of routine cystoscopy, selective cystoscopy, or no cystoscopy with benign hysterectomy.

STUDY DESIGN: We created a decision analysis model using TreeAge Pro. Separate models evaluated cystoscopy following abdominal, laparoscopic/robotic, and vaginal hysterectomy from the perspective of a third-party payer. We modeled bladder and ureteral injuries detected intraoperatively and postoperatively. Ureteral injury detection included false-positive and false-negative results. Potential costs included diagnostics (imaging, repeat cystoscopy) and treatment (office/emergency room visits, readmission, ureteral stenting, cystotomy closure, ureteral reimplantation). Our model included costs of peritonitis, urinoma, and vesicovaginal/ureterovaginal fistula. Complication rates were determined from published literature. Costs were gathered from Medicare reimbursement as well as published literature when procedure codes could not accurately capture additional length of stay or work-up related to complications.

RESULTS: From prior studies, bladder injury incidence was 1.75%, 0.93%, and 2.91% for abdominal, laparoscopic/robotic, and vaginal hysterectomy, respectively. Ureteral injury incidence was 1.61%, 0.46%, and 0.46%, respectively. Hysterectomy costs without cystoscopy varied from $884.89 to $1121.91. Selective cystoscopy added $13.20—26.13 compared with no cystoscopy. Routine cystoscopy added $51.39—57.86 compared with selective cystoscopy. With the increasing risk of injury, selective cystoscopy becomes cost saving. When bladder injury exceeds 4.48—11.44% (based on surgical route) or ureteral injury exceeds 3.96—8.95%, selective cystoscopy costs less than no cystoscopy. Therefore, if surgeons estimate the risk of injury has exceeded these thresholds, cystoscopy may be cost saving. However, for routine cystoscopy to be cost saving, the risk of bladder injury would need to exceed 20.59—47.24% and ureteral injury 27.22—37.72%. Model robustness was checked with multiple 1-way sensitivity analyses, and no relevant thresholds for model variables other than injury rates were identified.

CONCLUSION: While routine cystoscopy increased the cost $64.59—83.99, selective cystoscopy had lower increases ($13.20—26.13). These costs are reduced/eliminated with increasing risk of injury. Even a modest increase in suspicion for injury should prompt selective cystoscopy with benign hysterectomy.

Key words: cystoscopy, decision analysis, hysterectomy, urinary tract injury

For the 590,000 women who undergo hysterectomy annually in the United States, avoidance of surgical complications and rapid postoperative recovery are of paramount importance.[1] Among the common intraoperative complications, urinary tract injury (bladder or ureter) occurs in up to 4.3% of all hysterectomies.[2] When a urinary tract injury occurs, the risk of morbidity is significantly decreased if the injury is detected intraoperatively.

Failure to detect an intraoperative bladder or ureteral injury may result in peritonitis, urinoma, or fistula formation, with their accompanying morbidity and need for subsequent treatment. While cystoscopy may be used intraoperatively to detect such an injury, the question of how often it should be used remains controversial.

EDITORS' CHOICE

The optimal approach to cystoscopy at the time of benign hysterectomy is a clinical question that, owing to the low incidence of urinary tract injury, is not conducive to study in a randomized fashion and so is well suited to decision analysis. In 2001, Visco et al[3] published a cost-effectiveness analysis of routine cystoscopy to identify ureteral injury at the time of hysterectomy. They found routine cystoscopy to be cost saving when the rate of ureteral injury exceeded 1.5% at the time of abdominal hysterectomy or 2% in the case of vaginal or laparoscopically assisted vaginal hysterectomy.

Intuitively, with increasing rates of urinary tract injury, the cost of cystoscopy will be offset by the ability to avoid costs associated with detection and treatment of postoperatively identified injuries. Since that time, a number of changes in clinical practice make the question worth revisiting. Notably, total laparoscopic hysterectomy (as opposed to laparoscopically assisted vaginal hysterectomies) has become a more commonly used surgical approach, and robotic hysterectomy has emerged as an entirely new modality, with laparoscopic and robotic modalities now comprising 43.4% of hysterectomies performed annually in the United States.[4] Bladder injuries, also potentially detected with cystoscopy, remain more common than

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AJOG at a Glance

Why was this study conducted?

To assess the costs of 3 distinct approaches to cystoscopy at the time of hysterectomy.

Key findings

Performing selective cystoscopy minimally increases cost per hysterectomy at baseline but becomes cost saving when risk of urinary tract injury exceeds a modest threshold.

What does this study add to what is known?

- Significantly expands upon and updates 2001 analysis by Visco et al.
- Provides strong evidence to support use of selective cystoscopy at the time of hysterectomy.

ureteral injuries and may be added to the model.

Finally, the approach to injury detection and treatment has evolved and the associated costs have increased. Our nuanced model includes the costs of detection of an injury (retrograde pyelogram, computed tomography) as well as options for treatment of the sequelae (stent placement, fistula repair).

We performed a decision analysis comparing 3 strategies for detection of bladder or ureteral injury at the time of benign hysterectomy: no cystoscopy (base case), selective cystoscopy, and routine cystoscopy. In the case of selective cystoscopy, a surgeon would be required to make an intraoperative determination as to whether the case led to an above-average risk of urinary tract injury and would perform cystoscopy only in these high-risk cases.

Because the type and risk of injury varies with route of hysterectomy, separate models were created for abdominal, vaginal, and laparoscopic/robotic hysterectomy. We hypothesized that while routine cystoscopy may not be cost effective, there is at least some role for cystoscopy at the time of benign hysterectomy, regardless of surgical route.

Materials and Methods

We created 3 separate decision analysis models using TreeAgePro (TreeAge Software Inc, Williamstown, MA) for each of the hysterectomy modalities. The Figure represents a simplified diagram of our decision tree. We modeled ureteral and bladder injury detected intraoperatively (with or without cystoscopy) and postoperatively (before or after discharge). We used the cost perspective of insurance reimbursement (Medicare) except when procedure codes could not capture additional length of stay or additional work-up related to injuries. These additional costs were gathered from published literature.

Probabilities used in the model were obtained from the published literature using PubMed (https://www.ncbi.nlm.nih.gov/pubmed/) to find relevant primary sources. When multiple high-quality studies indicated different probabilities of an event occurring, the probability used in the model was a weighted mean of all studies. This allowed for the findings from a study of 1000 participants to be weighted twice as heavily as a study enrolling 500 while still incorporating results from multiple high-quality publications. Table 1 shows the weighted probabilities of events included in the model and indicates the references for each.

We modeled 3 discreet cystoscopy strategies with resultant injury detection and costs. No cystoscopy was included as the default option because this is the most typical current cystoscopy strategy and because a do-nothing strategy is customarily included in cost-effectiveness analyses. Routine cystoscopy was the strategy that analyzed outcomes if all patients underwent cystoscopy at the time of hysterectomy. Selective cystoscopy was an intermediate option in which some underwent cystoscopy while others did not.

In this strategy, the model assumed surgeons would make an intraoperative decision regarding their assessment of urinary tract injury risk for that specific hysterectomy. They would then categorize this risk as being above average or below average, dichotomizing into 2 distinct groups. In the group with above-average risk, cystoscopy would always be performed, while in the group with below-average risk, cystoscopy would not be performed.

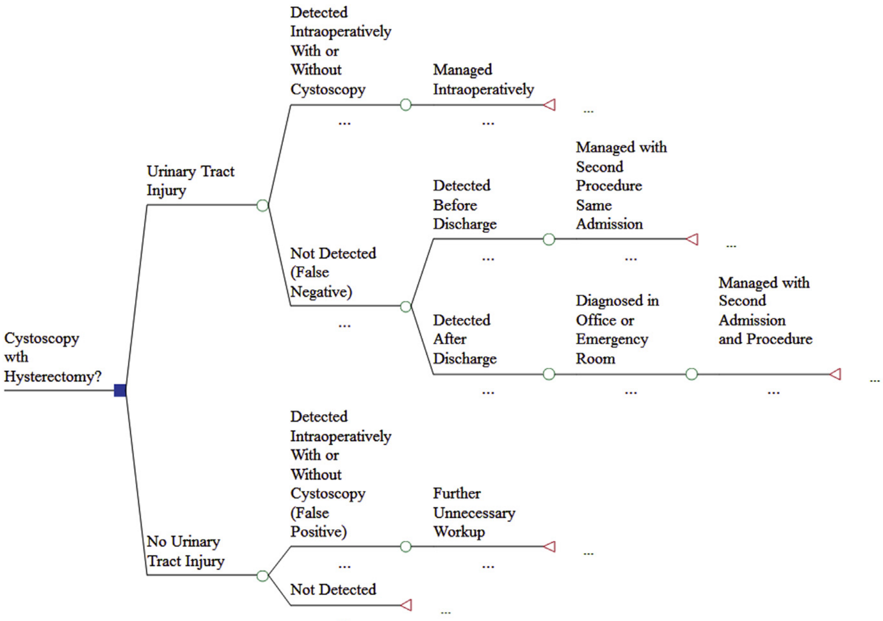
The overall risk of urinary tract injury was maintained at the same level as both routine cystoscopy and no cystoscopy. However, injury risk was adjusted based on surgeon assessment so it was higher in the high-risk group and lower in the low-risk group. However, there was still potential for injury and cystoscopic detection in both of these groups.

The following treatment paradigm was applied to all 3 cystoscopy strategies. In the case of an injury detected intraoperatively, we assumed bladder or ureteral injuries, either detected visually or with cystoscopic assistance, were repaired and costs of additional procedures and length of stay were included. Based on prospective data by Ibeanu et al,[2] our model estimated that 2.5% of cystoscopies would yield false-positive results for ureteral injury, leading to a reassuring intraoperative retrograde pyelogram. In the event of a true ureteral injury, abnormal retrograde pyelogram could lead to attempt at retrograde stent placement or reimplantation of the ureter.[5] Unsuccessful management with stenting would require ureteral reimplantation.

Those injuries not detected intraoperatively may or may not be detected prior to hospital discharge. Detection of a bladder injury prior to discharge was thought to be only possible in the case of abdominal hysterectomy, after which a patient would typically remain hospitalized for at least 2 nights.[6]

In this scenario, the typical patient would present with peritonitis on the second postoperative day, be diagnosed with computed tomography (CT) scan, and return to the operating room on the

FIGURE
Simplified diagram of decision tree



This decision tree analyzes possible outcomes for patients undergoing benign hysterectomy with plan for no cystoscopy, selective cystoscopy, or routine cystoscopy. Not all branches in the actual model are shown for simplicity purposes.

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third postoperative day. Those who return home without a diagnosis of a bladder injury, following any modality of hysterectomy, could develop peritonitis and urinoma, leading to a CT scan in the emergency department or could develop vesicovaginal fistula, which would be diagnosed with office cystoscopy.

We assumed that all vesicovaginal fistulae could be repaired with a modified Latzko procedure on the first attempt and would stay 1 night in the hospital, whereas those presenting with peritonitis would require a 3 night hospitalization. Depending on the mode of hysterectomy, 16.7–40.0% of ureteral injuries could remain undetected despite cystoscopy, with these false-negative rates included in the model. Rates were highest for laparoscopic and robotic hysterectomy, in which thermal energy is most heavily used.[7–9]

Delayed diagnosis of a ureteral injury would be detected with a CT scan and would require repair either with stenting or reimplantation. The possibility for failed stenting with subsequent reimplantation was included in the model with costs of hospital stay, subsequent office cystoscopy, stent removal, and renal ultrasound.

We recognize that there are potentially limitless scenarios for how these injuries might be treated in clinical practice. However, after consulting with 8 urologists at multiple institutions throughout the country, we determined that these treatment paradigms were widely accepted and were the most commonly described algorithms.

We also realized that inclusion of alternatives beyond those described would require knowledge of the percentage each was used, which would have been impractical to model because of lacking data. While this may be a simplified treatment plan, we believe that it was the most accurate attempt to model clinical practice while working within the confines of available data.

Costs were gathered from Medicare physician fee schedule reimbursement data or published literature and are reflected in Table 2.[10] Costs were converted to 2017 US dollars when necessary using consumer price index tables and year-specific currency conversion rates. Our time horizon was 90 days to account for the globally covered operative period and account for relevant postoperative events related to urinary tract injuries. Therefore, no discount rate was necessary.

Different literature reports costs differently and may include hospital charges, hospital reimbursement, or hospital costs with huge differences in costs based on perspective. While the use of the physician fee schedule in this decision analysis may appear to have lower than anticipated costs overall, it is recognized as a standard cost source for these analyses that accurately standardizes costs across different US regions and subspecialties. We therefore believed it was the most accurate choice for this analysis.

Model robustness was assessed using multiple 1-way sensitivity analyses. We took each model input variable and reran the model in multiple iterations changing the input variables across its plausible range to determine whether there is a threshold in which the model outcome would be changed. This determines what would happen if our base case assignments for the model variables were incorrect and how this would impact model outcomes. Percentages were varied from 0% to 100% and costs were varied from 50% to 200% of the baseline costs.

Results

Based on prior literature, bladder injury incidence was 1.75%, 0.93%, and 2.91% for abdominal, laparoscopic/robotic, and vaginal hysterectomy, respectively.[2,9,11] Ureteral injuries occur in 1.61%, 0.46%, and 0.46%, respectively.[8,9,12,13] The model's average hysterectomy costs with no cystoscopy varied from $884.89 to $1121.91.

Selectively performing cystoscopy adds between $13.20 and $26.13 to the cost of surgery, depending on the modality of hysterectomy (Table 3). With increasing risk of urinary tract injury, these costs are offset by savings that come from intraoperative, rather than delayed diagnosis,

TABLE 1
Probability of outcomes

Variable	Source	Base case model probability	Range of data from sources
Bladder injury, abdominal	Aarts et al[1]	0.0175	N/A
Bladder injury, vaginal	Teeluckdharry et al[11] Ibeanu et al[2] Chi et al[9]	0.0291	0.0066—0.0441
Bladder injury, laparoscopic/robotic	Chi et al[9] Adelman et al[12] Tan-Kim et al[8] Jelovse et al[13]	0.0093	0.0062—0.0317
Ureteral injury, abdominal	Aarts et al[1]	0.0161	N/A
Ureteral injury, vaginal	Teeluckdharry et al[11] Ibeanu et al[2] Chi et al[9] Anand et al[7] Aarts et al[1]	0.0046	0.0001—0.0276
Ureteral injury, laparoscopic/robotic	Chi et al[9] Adelman et al[12] Tan-Kim et al[8] Jelovsek et al[13] Aarts et al[1]	0.0046	0.0028—0.0079
Detection of cystotomy without cystoscopy, abdominal	Chi et al[9] Ibeanu et al[2]	0.4651	0.3750—0.5789
Detection of cystotomy without cystoscopy, vaginal	Chi et al[9] Ibeanu et al[2]	0.5128	0.3750—0.7333
Detection of cystotomy without cystoscopy, laparoscopic/robotic	Tan-Kim et al[8] Jelovsek, et al[13] Chi et al[9]	0.7941	0.5000—0.9200
Detection of ureteral injury without cystoscopy, abdominal	Chi et al[9] Ibeanu et al[2]	0.1052	0.0666—0.2500
Detection of ureteral injury without cystoscopy, vaginal	Chi et al[9] Anand et al[7] Ibeanu et al[2]	0.0333	0—0.0666
Detection of ureteral injury without cystoscopy, laparoscopic/robotic	Tan-Kim et al[8] Ibeanu et al[2]	0.1176	0.0666—0.1579
Cystoscopy false positive for bladder injury	Assumed[a]	0	N/A
Cystoscopy false negative for bladder injury	Assumed[a]	0	N/A
Cystoscopy false positive for ureteral injury	Ibeanu et al[2]	0.0250	N/A
Cystoscopy false negative for ureteral injury (denominator is those with injury who got a cystoscopy)	Anand et al,[7] vaginal Tan-Kim et al,[8] laparoscopic Chi et al,[9] abdominal	0.1666 vaginal 0.4000 laparoscopic/robotic 0.3333 abdominal	N/A
Postoperative diagnosis of bladder injury before discharge, abdominal only	Cohen et al[6]	0.25	N/A
Postoperative diagnosis of bladder injury after discharge presenting with vesicovaginal fistula (remainder with peritonitis/urinoma) all routes	Assumed[a]	0.5	N/A
Sensitivity of retrograde	Assumed[a]	1.0	N/A
Specificity of retrograde	Assumed[a]	1.0	N/A

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TABLE 1
Probability of outcomes *(continued)*

Variable	Source	Base case model probability	Range of data from sources
Ureteral injury, stent attempted	Assumed[a]	1.0	N/A
Ureteral injury stent placed, all modalities	Chung et al[5]	0.8400	N/A
Ureteral injury, stent sufficient, all modalities	Chung et al[5]	0.5714	N/A
Postoperative diagnosis of ureteral injury before discharge, all modalities	Patil et al[17]	0.0769	N/A
Postoperative diagnosis of ureteral injury after discharge with ureterovaginal fistula (rest have peritonitis), all modalities	Assumed[a]	0.5000	N/A

[a] For branches in which there were no available data in the published literature, the baseline values listed in Table 1 were assumed based on expert opinion. These values were then subjected to a sensitivity analysis in which the probability was varied from 0% to 100%. In no case did altering these values change the outcome of the model overall.

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which is more costly. Once bladder injury surpasses 4.48% at the time of abdominal hysterectomy, 5.49% at the time of vaginal hysterectomy, or 11.44% at the time of laparoscopic/robotic hysterectomy, selective cystoscopy becomes cost saving. Similarly, if ureteral injury exceeds 3.96% for vaginal hysterectomy, 6.31% for abdominal, or 8.96% for laparoscopic/robotic, it is cost saving to perform selective cystoscopy.

The threshold in the previous text, in which routine cystoscopy is cost saving, is notably higher than both no cystoscopy and selective cystoscopy. Routine cystoscopy adds an additional $51.39—57.86 above the cost of selective cystoscopy. Only when bladder injury reaches 20.59% for abdominal hysterectomy does this strategy reduce costs compared with selective cystoscopy. The incidence of injury required for cost savings is higher still with other hysterectomy modalities.

With respect to the ureters, the chance of injury must be at least 27.22% at the time of vaginal hysterectomy, 33.90% during abdominal hysterectomy, or 37.72% with laparoscopic/robotic hysterectomy before routine cystoscopy is cost saving. Given these high thresholds, it is unlikely that routine cystoscopy would ever be a cost-saving strategy compared with selective cystoscopy.

In multiple 1-way sensitivity analyses, no reasonable thresholds were identified other than the rate of ureteral and bladder injury. These were the 2 variables in the model most sensitive to change, with changes to other variables not appearing to alter model outcomes. This speaks to model robustness and lends stronger credence and validity to the outcomes of our model.

Comment

In this decision analysis, we sought to quantify the costs of performing no cystoscopy, selective cystoscopy, or routine cystoscopy at the time of benign hysterectomy. With separate models unique to each modality of hysterectomy, we found that selective cystoscopy cost an additional $13.20—26.13 per case over no cystoscopy. If a surgeon performing abdominal hysterectomy estimates the risk of bladder injury to be at least 4.48% or the chance of ureteral injury to be at least 6.31%, the intraoperative decision to perform cystoscopy is cost saving. A surgeon performing a vaginal hysterectomy estimating at least a 5.49% chance of bladder injury or a 3.96% risk of ureteral injury would also reduce costs by performing cystoscopy.

We found that the use of cystoscopy as a screening tool for urinary tract injury became cost saving with increasing risk of injury. While this fundamental principle is the same as that described by Visco et al,[3] the threshold above which cystoscopy becomes cost saving is notably higher in our model.

Several factors may account for this discrepancy. One is that our study allowed for the possibility of visual detection of a ureteral injury without cystoscopy, rendering cystoscopy beneficial only in those cases in which an injury could not be otherwise detected.

Another is that we included the possibility of cystoscopy resulting in absence of ureteral efflux even when no injury was present. Such a false-positive result would necessitate a retrograde pyelogram, thereby increasing the costs of cystoscopy.

Finally, both models assumed that greater costs would be incurred to treat an injury diagnosed postoperatively as compared with one diagnosed intraoperatively. However, we included both a larger percentage whose ureteral injury would be treated successfully with stenting, and we also included bladder injuries in the analysis that were more likely to be diagnosed intraoperatively. Both of these changes reduced the marginal cost of cystoscopy and increased the injury threshold needed for cost neutrality.

The decision as to whether to perform cystoscopy intraoperatively is more than a financial one. We elected not to include quality-of-life data because we found there to be insufficient data to guide the decisions necessary for creation of a valid model, whereas cost data proved more reliable. However, one can imagine a hospital or health system in which the risk of urinary tract injury is exactly at the threshold, where it will cost an equal amount to the institution whether cystoscopy is performed during select hysterectomies or not.

TABLE 2
Costs included in decision tree

Variable	Cost (2017 $US)
Abdominal hysterectomy	1042.19
Vaginal hysterectomy	887.03
Laparoscopic hysterectomy	858.41
Cystoscopy	85.68
Cystoscopy with ureteral stenting	162.72
Repair of bladder injury	776.87
Repair of vesicovaginal fistula	630.23
Ureteral reimplantation	1155.95
Additional hospital day after surgery	837.39
Emergency department visit	147.78
CT with contrast	317.52
Retrogade cystogram	38.88
Retrograde pyelogram	156.96
Stent removal and retrograde pyelogram	315.00
Lasix renal scan	386.64
Simple cystometrogram	193.32
Renal ultrasound	116.28

CT, computed tomography.
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Clearly, the patients suffering a complication at those centers using selective cystoscopy are more likely to benefit from intraoperative detection of their injuries and prompt treatment. Despite the complication, they receive a higher quality of care, experience less morbidity, and may be less likely to litigate, a consequence whose cost we did not consider in our model.

Finally, surgeons may benefit in an unquantifiable way from the reassurance of a negative cystoscopy when they leave the operating room to attend to other duties.

Our study has several limitations. As with any decision analysis, the quality of the results is directly related to the quality of the assumptions made in the model. The clinical course of a typical patient with a urinary tract injury was determined by the authors along with expert opinion of 8 urologists at 6 institutions throughout the United States. Point estimates for probabilities in the decision tree were taken from best available literature. In circumstances in which no prospective evidence was available, we relied on retrospective data. To counteract the deleterious effects of potential inaccuracies in these data and to demonstrate robustness of the model, we performed multiple 1-way sensitivity analyses to show that reasonable variability in model inputs would not greatly change our conclusions.

The lack of meaningful thresholds on sensitivity analyses yields strength to our conclusions. We considered using a probablistic sensitivity analysis, but with difficulty assigning distributions based on available data, we decided that performing multiple 1-way sensitivity analysis was a more valid approach.

Finally, our model specifically used inputs from benign hysterectomy, and

TABLE 3
Incremental costs and thresholds of cystoscopy strategies by modality

Finding	Abdominal	Laparoscopic or robotic	Vaginal
Incremental cost of selective cystoscopy over no cystoscopy	$15.03	$26.13	$13.20
Incremental cost of routine cystoscopy over selective cystoscopy	$52.27	$57.86	$51.39
Bladder injury rate above which selective cystoscopy costs less than no cystoscopy	4.48%	11.44%	5.49%
Ureteral injury rate above which selective cystoscopy costs less than no cystoscopy	6.31%	8.96%	3.96%
Bladder injury rate above which routine cystoscopy costs less than selective cystoscopy	20.59%	47.24%	22.95%
Ureteral injury rate above which routine cystoscopy costs less than selective cystoscopy	33.90%	37.72%	27.22%

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our findings should not be generalized to hysterectomy performed for an indication of malignancy or to cases performed concomitantly with other procedures that carry an increased risk or urinary tract injury.

Our model suggests that selective cystoscopy is the best option in the case of benign hysterectomy as it minimally increases cost per hysterectomy but becomes cost saving with modest increases in risk of injury. Even when the threshold for cost savings is not exceeded, the cost of cystoscopy is quite small when compared with the cost of hysterectomy overall.

Given our findings, we advocate that a surgeon performing hysterectomy by any modality implement selective cystoscopy by assessing intraoperatively whether the surgery has placed that specific patient at above-average risk of urinary tract injury and perform cystoscopy on this subset of cases.

Multiple studies have examined factors that may predispose patients to urinary tract injury, including endometriosis, enlarged fibroid uterus, history of prior cesarean delivery, and American Society of Anesthesiologists class 3 or 4 status. With the exception of higher American Society of Anesthesiologists classification, each of these factors may lead to anatomic distortion and greater technical difficulty. It is recognition of such anatomic distortion or technical difficulty within a given case that we believe should prompt a surgeon to consider cystoscopy.[8,14–16]

Even a high-volume surgeon with a known low rate of bladder or ureteral injury may for a given case suspect that the risk of injury is elevated and would be justified in performing cystoscopy. Furthermore, there may be capable surgeons who do not feel confident predicting the difference between 2% and 8% risk of injury and for whom a low index of suspicion is well advised. Meticulous surgical technique is required to avoid urinary tract injury in hysterectomy patients. For those cases in which it cannot be prevented, cystoscopy adds minimal increased costs and provides a means to optimize outcomes. ■

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