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## Corneal Abrasion in Hysterectomy and Prostatectomy: The Role of Laparoscopic and Robotic Assistance

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### Abstract

**Background**—Radical prostatectomy (RP) is most commonly performed laparoscopically with a robot (robotic-assisted laparoscopic radical prostatectomy, R/PROST). Hysterectomy, which may be open hysterectomy (O/HYST), or laparoscopic (L/HYST), has been increasingly frequently done *via* robot (R/HYST). Small case series suggest increased corneal abrasions (CA) with less invasive techniques.

**Methods**—We identified RP (166,942), O/HYST (583,298), or L/HYST (216,890) discharges with CA in the Nationwide Inpatient Sample (2000–2011). For 2009–11, we determined odds

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Conflict of Interest Statement: Drs. Sampat, Glick, Lee, Tenney, and Eggener, and Messrs. Kunnavakkam and Parakati report no conflict of interest. Dr. Roth has served as an expert witness in cases of perioperative eye injuries on behalf of patients, physicians, and hospitals.

ratios (OR) and 95% confidence intervals (CI) for CA, in R/PROST, non-R/PROST, L/HYST, O/HYST, and R/HYST. Uni- and multivariate models studied CA risk depending upon surgical procedure, age, race, year, chronic illness, and malignancy.

**Results**—In 2000–11, 0.18% RP, 0.13% L/HYST, and 0.03% O/HYST sustained CA. Compared to 17,554 non-R/PROSTs (34 abrasions, 0.19%) in 2009–11, OR was not significantly higher in 28,521 R/PROSTs (99, 0.35%; OR 1.508, CI 0.987–2.302,  $P < 0.057$ ). CA significantly increased in L/HYST (70/51,323; 0.136%) vs O/HYST (70/191,199; 0.037%, OR 3.821, CI 2.594–5.630,  $P < 0.0001$ ), further increasing in R/HYST (63/21, 213; 0.297%, OR 6.505, CI 4.323–9.788,  $P < 0.0001$ ). For hysterectomy, risk of CA increased with age (OR 1.020, CI 1.007–1.034,  $P < 0.003$ ), and number of chronic conditions (OR 1.139, CI 1.065–1.219,  $P < 0.0001$ ). CA risk was likewise elevated in R/HYST with number of chronic conditions. Being African-American significantly decreased CA risk in R/PROST and in R/ or L/HYST.

**Conclusions**—L/HYST increased CA nearly 4-fold, and R/HYST about 6.5-fold vs O/HYST. Identifiable preoperative factors are associated with either increased risk (age, chronic conditions) or decreased risk (race).

## Introduction

Prostate cancer, the most common non-skin male cancer in the United States, is also the second most frequent cancer death. Radical prostatectomy (RP) is conventional for clinically-localized cancer. Robotic-assisted laparoscopic radical prostatectomy (R/PROST) has advantages of shortened hospital stay, and decreased blood loss, morbidity, and post-operative analgesia compared to open prostatectomy (OP).<sup>1</sup>

Hysterectomy has been performed for decades, for both malignant and benign disease, and in one in three women by age 60.<sup>2</sup> With faster recovery, less pain, and fewer overall complications, robotically-assisted laparoscopic hysterectomy (R/HYST) has increased dramatically, although without clear benefit for benign disease.<sup>3</sup> In malignancy, initial outcomes of robotic surgery are encouraging.<sup>4,5</sup>

Retro- or prospective studies of anesthetic complications are lacking in R/HYST, but reported challenges of R/PROST are altered respiratory mechanics, laryngeal edema, and brachial plexus injuries.<sup>1</sup> In a small study of 1,500 R/PROST patients, corneal abrasion (CA) was the most reported anesthesia-related complication (3%).<sup>6</sup> Since R/HYST and R/PROST share steep head down positioning, pneumo-peritoneum, and a surgical learning curve, among other similarities, we hypothesized a similar incidence of eye-related complications.<sup>7,8</sup>

We aimed to determine the incidence of CA following prostatectomies and hysterectomies, to test the hypothesis that laparoscopic or robot assistance increases risk, and to examine risk factors. Rapid introduction of the robot for RP rendered it difficult to study the influence of laparoscopy vs robotic assistance on CA. However, hysterectomy, a similar procedure, is easily identifiable as open, laparoscopic, or robotic assisted. We used the Nationwide Inpatient Sample (NIS), a large administrative discharge database that allows study of low frequency events.<sup>9</sup> CA is painful and disturbing, and has been targeted for anesthesia

performance improvement as potentially preventable.<sup>10</sup> With robotically-assisted surgery increasing, it is important to understand the increased risks of these unexpected, and painful perioperative complications.

## Materials and Methods

### Data Sources

Data were extracted for 2000–2011 from the NIS, the largest United States all-payer hospital inpatient database. With over 1,000 randomly selected hospitals in 44 states, it is an approximately 20% stratified sample, including public hospitals and academic medical centers. As part of the Healthcare Cost and Utilization Project (HCUP), NIS is maintained by the Agency for Health Care Research and Quality. Hospitals and discharges are weighted based on the number of hospitals and discharges in the database.<sup>i</sup>

A typical hospital discharge includes patient demographics (age, sex, race), diagnoses (principal and 14 secondary), procedures (principal and 14 secondary), charges, length of stay, discharge status, outcomes, and number of chronic conditions.<sup>ii</sup> Diagnosis and procedure data are coded using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). Quality control and reliability of the NIS have been examined each year since 2000.<sup>iii</sup> National estimates of essential health care parameters in the NIS were precise and accurate compared with the American Hospital Association Annual Survey, National Hospital Discharge Survey, and Medicare Inpatient data.<sup>iv</sup> Our Institutional Review Board deemed the study “exempt.”

### Population of interest and surgical procedure

Discharges with RP, open hysterectomy (O/HYST), or laparoscopic hysterectomy (L/HYST) were identified using ICD-9-CM procedure codes (table 1), and confirmed with Encoder Pro.com (Optum, Salt Lake City, UT). While the L/HYST codes were specific, to identify laparoscopic RP required modifier code 51.42. However, most of the RPs in NIS from 2009–11 were either OP or robotic assisted, with few identifiable as laparoscopic, without robotic assistance. Because the number of laparoscopic, non-robotically assisted RPs in NIS was only 376, we eliminated these for insufficient sample size (fig. 1). As recognized by the National Center of Health Statistics and the Centers for Medicare and Medicaid Services, beginning October 1, 2008, the robot-assisted modifier codes (ICD-9-CM 17.42 and 17.44) were introduced to specifically identify R/PROST as well as R/HYST. Thus, discharges with procedure codes for both RP, and the robot-assisted modifiers were classified as R/PROST, while those that only had the procedure code for RP as non-R/PROST, *i.e.*, OP (table 1 and fig. 1). L/HYST discharges that contained 17.42 or 17.44 codes were classified as R/HYST.

<sup>i</sup>HCUP Nationwide Inpatient Sample (NIS). Healthcare Cost and Utilization Project (HCUP), 2000–2009. Rockville, MD: Agency for Healthcare Research and Quality. Available at: <http://www.hcup-us.ahrq.gov/nisoverview.jsp>. Accessed April 10, 2012.

<sup>ii</sup>HCUP Chronic Condition Indicator. Healthcare Cost and Utilization Project (HCUP). November 2011. Agency for Healthcare Research and Quality, Rockville, MD. [www.hcup-us.ahrq.gov/toolssoftware/chronic/chronic.jsp](http://www.hcup-us.ahrq.gov/toolssoftware/chronic/chronic.jsp). Accessed December 18, 2012.

<sup>iii</sup>NIS Comparison Reports, 1999–2009. Rockville, MD: Agency for Healthcare Research and Quality. Available at: <http://www.hcup-us.ahrq.gov/db/nation/nis/nisrelatedreports.jsp>. Accessed April 10, 2012.

<sup>iv</sup>Whalen D, Houchens R, Elixhauser A. 2004 HCUP Nationwide Inpatient Sample (NIS) Comparison Report. HCUP Methods Series Report #2007-03. Rockville, MD: U.S. Agency for Healthcare Research and Quality, 2007. Available at: <http://www.hcup-us.ahrq.gov/reports/methods.jsp>. Accessed April 10, 2012.

Since the robotic modifier code was introduced in late 2008, we limited robotic modifier codes to 2009–2011. At the time of our analysis, 2011 was the most current database. CA was identified as ICD-9-CM 371.20.

### Comparisons of Laparoscopic, and Robotic Assisted Prostatectomies or Hysterectomies

We extracted all discharges containing R/PROST and non-R/PROST, R/HYST, L/HYST, and O/HYST in 2009–2011, and those that also had discharge codes corresponding to CA. We calculated CA incidence and the number needed to harm (NNH); also, we compared age, race, and number of chronic medical conditions between the groups, as we previously reported.<sup>9</sup> Odds ratios (OR) were calculated by univariate and multivariable analysis. Moreover, within univariate and multivariable analysis, we assessed R/HYST and L/HYST within a categorical variable “Modified Hysterectomy” having two levels for each procedure variant. For hysterectomy, cases were segregated as malignant vs non-malignant using ICD-9-CM codes: 180 (carcinoma of the cervix), 182 (carcinoma of the uterus), and 183 (carcinoma of the fallopian tubes and broad ligament).

### Statistical Analysis

Data were analyzed with STATA v13.0 (Stata Corporation, College Station, TX). All R/PROST and OP discharges, and separately, those discharges with diagnostic codes for CA were compared between groups for mean age and number of chronic conditions using an independent sample, 2-tailed t test, and proportions of distribution according to race (White, African American) using chi square, and  $P < 0.05$  significant. For R/HYST, L/HYST, and O/HYST, 3-way comparisons used ANOVA with Bonferroni correction for three comparisons to compare mean age and mean number of chronic conditions;  $P < 0.05$  was significant. Chi square assessed race distributions, and the presence of malignancy, and were corrected for multiple pairwise comparisons with  $P < 0.05/3 = 0.017$ .

To examine factors increasing CA risk in RP and hysterectomy, we first used univariate analysis. As prostatectomy and hysterectomy are distinct procedures on opposite genders, we maintained separate analyses. Age, number of chronic conditions, race, surgery year, malignancy diagnosis, and robotic or laparoscopic procedure were examined. For univariate analysis,  $P < 0.2$  was the cutoff for entering parameters into the subsequent multiple regression analysis.

Collinearity tests were performed on remaining candidate parameters. Continuous, increasing variables including age and number of chronic conditions were compared through Pearson correlations, and discrete variables including malignant, robotic, laparoscopic, and race were compared using chi-square. Unpaired t-tests compared continuous and discrete variables. Correlations above 0.5 with  $P < 0.05$  were deemed significant, as were  $P$ -values  $< 0.05$  for unpaired t-tests and chi-2 tests.

Multiple logistic regression was performed using procedure modifiers, and the additional covariates age, number of chronic conditions, malignancy, race, and year in RP, and separately in hysterectomy. These models thus considered the impact of surgical technique on CA in the context of all the background covariates, effectively controlling for differences between group compositions. Forward and backward elimination yielded the same results.

An area under the receiver operating characteristic (ROC) curve  $> 0.5$  and Hosmer and Lemeshow  $P > 0.05$  were the thresholds for confirming the goodness of fit, and validity of these models, respectively.

## Results

### The overall incidence of corneal abrasion in radical prostatectomy and hysterectomy

NIS contained 166,942 RP discharges from 2000–2011, with 295 CAs (0.18%, 1.8 per thousand, (table 2). The total number of CAs during this same time period increased; in 2000 there were  $< 10$  discharges with CA (no more than 0.08%, 0.8 per thousand), while in 2011 there were 46 (0.28%, 2.8 per thousand), an increase of about 3-fold. (NIS does not permit reporting of research results with individual values  $< 10$ , hence, these are expressed as “ $<10$ ”). We identified 216, 890 L/HYST discharges from 2000–2011, amongst them were 275 with CA, 0.13%, or 1.3 per thousand. There were less than 10 CAs in 2000 ( 0.09%, or 0.9 per thousand), and 55 (0.21%, 2.1 per thousand), an approximate 2-fold increase, in 2011 (table 2). The rate of CA in O/HYST remained stable during 2000–11, an overall rate of 0.03%, or 0.3 per thousand (table 2).

### Patient characteristics and incidence of corneal abrasion in laparoscopy and/or robotic assistance vs open or non-robotically assisted surgery

In 2009–2011, of 28,521 discharges with R/PROST, there were 99 CAs (3.5 per thousand); whilst 17,554 discharges with OP had 34 CAs (1.9 per thousand, table 3). Among all discharges with R/PROST or OP, the latter had a greater mean number of chronic conditions ( $P < 0.0001$  by unpaired t test), and a higher proportion of African-Americans ( $P < 0.0001$  by chi square). Patients undergoing R/PROST and OP who developed CA were not significantly different in age, number of chronic conditions, or race, (table 3).

In hysterectomy, among 191,199 O/HYST, there were 70 CAs (0.4 per thousand) while in L/HYST, there were 70 in 51,323 (1.4 per thousand), and when robotic assistance (R/HYST) was used, CA was in 63 of 21,123 (3.0 per thousand, table 3). R/HYST patients were significantly older and had greater average number of chronic conditions vs O/HYST and L/HYST, and contained a lower proportion of African-Americans compared to O/HYST (table 3). Moreover, L/HYST discharges were significantly younger, had lower average number of chronic conditions, a lower proportion of African-Americans, and lower proportion of malignancy compared to O/HYST. R/HYST had significantly higher proportions of malignancy diagnoses compared to the other two groups. Among those discharges with CA, those who underwent R/HYST or L/HYST had fewer chronic conditions compared to O/HYST ( $P < 0.013$  and  $P < 0.018$ , respectively); by repeated pairwise chi square testing, those with CA who underwent R/HYST consisted of a higher proportion of diagnoses of malignancy compared to L/HYST (table 3).

### Univariate analysis to identify risk factors for corneal abrasion

Univariate analysis (table 4) identified factors increasing risk for inclusion in multivariable analysis; terms with  $P < 0.2$  were considered significant for inclusion in the final models

(table 5). For RP, being African American conferred lower risk (OR 0.06, 95% CI 0.01–0.44,  $P < 0.005$ ) while robotic use increased risk (OR 1.55, 95% CI 1.01–2.36,  $P < 0.043$ ).

Robotic usage increased CA risk in hysterectomy (OR 7.78, 95% CI 5.23–11.57,  $P < 0.0001$ ), as did laparoscopy (OR 3.69, 95% CI 2.52–5.41,  $P < 0.0001$ ). Increasing age, chronic conditions, calendar year of surgery, and a malignant diagnosis all increased CA risk, while being African-American significantly lowered the risk of CA (table 4).

### **Prostatectomy and Hysterectomy: Risk factors for corneal abrasion by multivariable regression analysis**

By multiple regression analysis that considered for prostatectomy the background covariates surgical procedure, age, number of chronic conditions, age, race, and year of surgery, robotic assistance did not significantly increase the risk of CA; for robotic assistance, OR was 1.508 (95% CI 0.987–2.302,  $P < 0.057$ ). However, being African-American was a significant negative risk factor (OR 0.062, 95% CI 0.009–0.446,  $P < 0.006$ , table 5). Hosmer and Lemeshow P was 0.9435 and area under the ROC curve 0.6003.

In hysterectomy, malignancy or benign diagnosis was included in the multiple regression analysis, in addition to the above, same covariates as for prostatectomy. Both laparoscopic and robotic usage (assessed as two levels in the factor variable “Modified Hysterectomy”) significantly increased CA; for L/HYST, OR was 3.821 (95% CI 2.594–5.630,  $P < 0.0001$ ), and in R/HYST, OR was 6.505 (95% CI 4.323–9.788,  $P < 0.0001$ , table 5). Additional factors that increased risk in hysterectomy included advancing age (OR 1.020, 95% CI 1.007–1.034,  $P < 0.003$ ), and increasing number of chronic conditions (OR 1.139, 95% CI 1.065–1.219,  $P < 0.0001$ , table 5). Hosmer and Lemeshow P was 0.6558 and area under the ROC curve 0.7850. As in prostatectomy, race was a significantly negative risk factor for CA (table 5).

Results of forward and backward elimination in the models were identical. To further test the model stringency, we tested collinearity and correlation to examine interactional effects within RP and hysterectomy. The only significant interactions were malignancy and age, and modified hysterectomy and number of chronic conditions, for hysterectomy (Supplemental Table 1).

## **Discussion**

Elucidating the mechanisms of CA was beyond the scope of this study, however several proposed etiologies of perioperative CA include exposure, reduced corneal hydration, and chemical or direct mechanical trauma.<sup>11</sup> Exposed corneas during general anesthesia had a significantly higher abrasion rate *vs* eyes that were covered, and a longer duration of operating time, *i.e.*, greater corneal exposure, increased the rate, with the peak incidence occurring between 90 and 150 min.<sup>12</sup> The latter study, however, was performed almost 40 years ago, when risks of CA were not as well recognized, and eye protection methods were not as universally practiced as they are today, which has resulted in significant reduction in incidence of these injuries.<sup>13</sup>

Another potential mechanism of injury in RP and hysterectomy is the increase in intraocular pressure (IOP) in steep Trendelenberg position during R/PROST,<sup>14</sup> L/HYST, and R/HYST. Surgeons request such positioning for surgical exposure and optimal robotic arm positioning. But high head down angles (40–45°) may not actually be necessary.<sup>15</sup> Corneal or conjunctival edema may also occur from increased central venous pressure<sup>16</sup> and raised IOP, causing further stress to the eye *via* direct fluid pressure on the globe, or pressure causing the eyes to tend to remain open. Further support for these hypotheses is that IOP increased when patients were positioned prone for spine surgery, which has also been associated with a higher incidence of CAs.<sup>17</sup>

About 80% of RPs have robotic assistance.<sup>18</sup> As a result of rapid introduction of the robot, there were few cases in NIS of laparoscopy alone (fig. 1). Hence, our comparison was exclusively of open prostatectomy to robotically-assisted laparoscopic surgery. Accordingly, the relative contributions in RP of laparoscopy and the robot to CA risk cannot be determined using this database. Surgery in the presence of malignancy would be expected to be more technically difficult, but in our study, there was no impact upon the risk of CA in patients undergoing R/HYST or L/HYST.

An unexpected finding was the apparent protective effect against CA, in African Americans in both RP and hysterectomy. There may be previously unrecognized differences in anatomy or eye structure that render African Americans less likely to sustain CAs. Similar findings have been suggested elsewhere.<sup>19</sup> Xian *et al*, *e.g.*, noted that African-Americans had lower mortality *vs* Whites.<sup>20</sup> Also, African Americans > 65 years had lower adjusted 30-day mortality than Whites after congestive heart failure, acute myocardial infarction, hip fracture, and gastrointestinal bleeding, which suggests a systemic *vs* disease specific effect.<sup>21,22</sup> Our finding may warrant further study using methodology not available in the NIS.

Multivariable analysis indicated a significantly greater risk of CA with advancing age in those undergoing modified hysterectomy. While this could be explainable as a decrease in tear production with aging, it is surprising that the findings were not present for R/PROST.

There are study limitations. NIS depends on the accuracy of diagnoses and procedure codes. But the coding for hysterectomy and prostatectomy is straightforward, as is the diagnosis code for CA, hence, errors in these codes are likely not a significant factor. NIS does not provide anesthetic techniques or length of surgery. With no surgeon identification, the effect of surgeon volume and/or the learning curve cannot be assessed. Verification of diagnosis in each case is also not possible. Although diagnostic codes on discharge records are taken to reflect those acquired during hospitalization, it is also possible that some of them are preexisting conditions, in which case, the rates might be overestimated.<sup>9</sup> However, CA is typically an injury from which there usually is complete recovery, and it is not likely the diagnosis code would be previously present on a subsequent discharge record.

As NIS lacks longitudinal data beyond the hospital discharge, we cannot assess the recovery from CA, its long-term impact, or increased medical costs. It would have been interesting to assess the impact of obesity, however, in less than ¼ of the L/HYST and RP cases in 2009–11 did we find specific body mass index codes. An important limitation of NIS in cancer

studies is the lack of adjustment for tumor stage, clinical features, and pathological findings.<sup>18</sup> Therefore, the relationship between these factors and difficulty, length, and other operative features, and CA, cannot be evaluated.

In conclusion, in a large United States nationwide sample, rates of CA have increased from 2000–2011 for RP and hysterectomy. In 2009 to 2011, there was an approximately 4-times higher risk when laparoscopy was used for hysterectomy, and a 7-times higher risk when laparoscopic hysterectomy was robotically-assisted, compared to an open procedure. Thus both laparoscopy and robotic assistance appear to contribute independently to increasing the risk of CA for hysterectomy. Age, the number of chronic conditions, and race were factors influencing the risk of CA. In light of the widening indications and use of robotic assistance,<sup>23</sup> clinicians should be vigilant and methods should be developed to lower the incidence of these eye injuries in the perioperative setting, and efforts to identify causative factors should be undertaken.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgments

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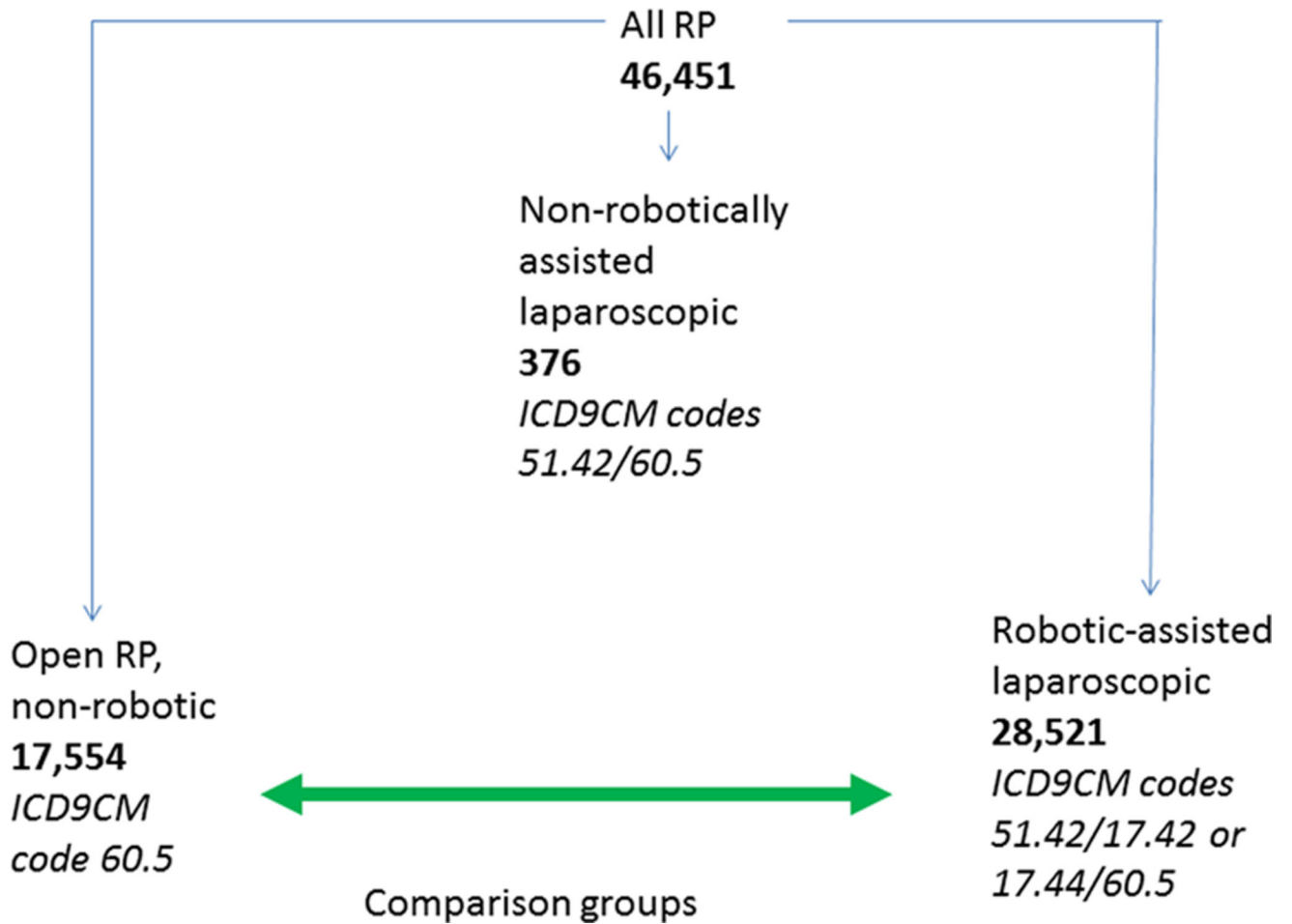
### Final Boxed Summary Statement

#### What we already know about this topic

- Laparoscopic and robotic assisted procedures typically take longer than open procedures and a small study suggested that they are associated with an increased risk of corneal abrasions

#### What this article tells us that is new

- In a review of nearly 1 million prostatectomy and hysterectomy cases from the National Inpatient Sample, corneal abrasion was not increased with robotic assisted prostatectomy
- Compared to open hysterectomy, risk of corneal abrasion was increased nearly 4-fold with the laparoscopic technique and nearly 6.5 fold with the robotic technique



**Figure 1.**  
Selection of discharges for radical prostatectomy  
Radical prostatectomy (RP) discharges were segregated according to ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) codes. The ICD-9-CM codes and the number of discharges are shown. Because there were few cases of prostatectomy using laparoscopy alone, we narrowed our study to a comparison of open vs robotically-assisted laparoscopic prostatectomy

**Table 1**

## ICD-9-CM Procedure Codes for Prostatectomy, Laparoscopic, and Open Hysterectomy

Procedure Code	Description
60.5	Radical prostatectomy
68.31	Laparoscopic supracervical hysterectomy
68.41	Laparoscopic total abdominal hysterectomy
68.51	Laparoscopic vaginal hysterectomy
68.61	Laparoscopic radical abdominal hysterectomy
68.71	Laparoscopic radical vaginal hysterectomy
68.39*	Other and unspecified subtotal abdominal hysterectomy
68.49*	Other and unspecified total abdominal hysterectomy
68.59*	Other and unspecified vaginal hysterectomy
68.69*	Other and unspecified radical abdominal hysterectomy
68.79*	Other and unspecified radical vaginal hysterectomy

\* The codes 68.39, 68.49, 68.59, 68.69, and 68.79 corresponded to open hysterectomy. Addition of the robotic modifier codes 17.42 and 17.44 allowed identification of discharges overlapping the 60.5 codes, and the laparoscopic hysterectomy codes, where robotic assistance was used. The code 51.42 was used for radical prostatectomy to identify laparoscopic assistance. See figure 1 for further explanation of the coding for prostatectomy.

ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification

**Table 2**

Yearly rates of corneal abrasion in radical prostatectomy (RP), laparoscopic hysterectomy (L/Hyst), and open hysterectomy (O/Hyst) in the Nationwide Inpatient Sample (NIS) from 2000 to 2011

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	TOTAL
<b>RP</b>	12,045	12,487	13,833	12,290	11,482	11,185	13,512	16,042	17,991	15,614	13,770	16,691	166,942
<i>Corneal Abrasion</i>	<10	<10	<10	<10	12	17	30	40	39	47	40	46	295
%	<0.08	<0.08	<0.07	<0.08	0.10	0.15	0.22	0.25	0.22	0.30	0.29	0.28	0.18
<b>L/Hyst</b>	11,469	12,171	13,193	14,319	15,638	15,961	17,718	21,190	22,785	23,041	23,467	25,938	216,890
<i>Corneal Abrasion</i>	<10	15	<10	<10	<10	14	14	30	36	40	38	55	275
%	<0.09	0.12	<0.08	<0.07	<0.06	0.09	0.08	0.14	0.16	0.17	0.16	0.21	0.13
<b>O/Hyst</b>	28,493	26,733	28,698	27,401	32,420	31,847	44,981	89,109	82,417	73,168	63,073	54,958	583,298
<i>Corneal</i>	<10	<10	<10	<10	<10	<10	16	35	32	24	23	23	189
%	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.03

We used ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) codes to identify all discharges with RP, L/HYST, and O/HYST. Note that for results less than 10, NIS does not permit exact numerical reporting.

**Table 3** Characteristics, all Patients, and for those specifically with Corneal Abrasion in Prostatectomy or Hysterectomy, 2009–2011

	Open prostatectomy (OP)	Robotic prostatectomy (R/Prost)	P (OP vs R/Prost)	Robotic Hysterectomy (R/Hyst)	Laparoscopic Hysterectomy (L/Hyst)	Open Hysterectomy (O/Hyst) ‡	P (3-way Hysterectomy comparisons, ANOVA)
<i>All patients: Number of discharges</i>	17,554	28,521	--	21,123	51,323	191,199	--
<i>Mean age: all patients (95% CI)</i>	61.4 (61.3–61.5)	61.5 (61.4–61.6)	0.1165	50.7**‡ (50.6–50.9)	46.0* (45.9–46.1)	48.7 (48.6–48.7)	0.0001
<i>Average # of chronic conditions: all patients (95% CI)</i>	3.4 (3.4–3.4)	3.3 (3.2–3.3)	0.0001	3.2**‡ (3.1–3.2)	2.8* (2.8–2.9)	3.0 (3.0–3.0)	0.0001
<i>White (%): all</i>	11,772 (76.3)	19,354 (77.3)	0.0001	13,367 (72.7)	32,282 (72.5)	104,476 (62.7)	0.0001
<i>AA (%): all</i>	2,047 (13.3)	2,772 (11.1)		2,014 (11.0)	5,036 (11.3)	30,434 (18.3)	*
<i>Benign (%): ‡ all</i>				16,209 (76.7)	48,332 (94.2)	169,284 (88.5)	0.0001
<i>Malignant (%): all</i>				4,914 (23.3)	2,991 (5.8)	21,915 (11.5)	
CA patients (per 1000)	34 (1.9/1000)	99 (3.5/1000)		63 (3.0/1000)	70 (1.4/1000)	70 (0.4/1000)	
NNH for CA		652		382	1002		
Mean age: CA (95% CI)	62.4 (60.3–64.4)	61.8 (60.5–63.2)	0.6846	54.0 (50.8–57.2)	52.0 (49.3–54.7)	54.9 (52.0–57.7)	0.354
Average # of chronic conditions: CA (95% CI)	3.3 (2.6–3.9)	3.2 (2.8–3.7)	0.9371	3.5** (3.0–4.0)	3.5 ‡ (3.1–4.0)	4.6 (4.0–5.2)	0.0053
White (%): ‡ CA	31 (96.9)	75 (90.4)	0.510	45 (84.9)	49 (80.3)	50 (86.2)	0.635
AA (%): CA	0 (0.0)	1 (1.2)		1 (1.9)	4 (6.6)	2 (3.5)	
Benign (%): ‡ CA				40 (63.5)	63 (90.0)	56 (80.0)	0.001
Malignant (%): CA				23 (36.5)	7 (10.0)	14 (20.0)	

\*  $P < 0.001$  vs O/Hyst;

‡  $P < 0.001$  vs L/Hyst;

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\*\*  $P < 0.013$  vs O/Hyst;‡  $P < 0.018$  vs O/Hyst;

‡ Reference group

Age and number of chronic conditions were compared between groups using unpaired t test or ANOVA with a Bonferroni correction for multiple comparisons. Race distribution was compared using Chi square. Pairwise comparisons between the groups used ANOVA with built-in Bonferroni and  $P < 0.05$  significant; or chi square, corrected for multiple comparisons, with  $P < 0.017$  significant between groups. The  $P$  values columns show statistical significance using unpaired t test, ANOVA, or chi square. Among all discharges with R/Prost or OP, OP had significantly greater mean number of chronic conditions and a higher proportion of African-Americans (AA). Among all Hyst, R/Hyst patients were older, had higher number of chronic conditions, a higher proportion of Whites, and of malignancy. Patients undergoing R/Prost and OP who developed CA were not significantly different in age, number of chronic conditions, or race. Patients undergoing R/Hyst and L/Hyst who developed CA had fewer number of chronic conditions vs O/Hyst; there was a significantly higher proportion of patients with malignancy in those undergoing R/Hyst vs L/Hyst.

ANOVA = analysis of variance; CA = comel abrasion; CI = 95% confidence interval; L/Hyst = laparoscopic hysterectomy; NNH= number needed to harm; O/Hyst = open hysterectomy; OP = open prostatectomy; R/Hyst= robotic assisted laparoscopic hysterectomy; R/Prost = robotic assisted laparoscopic radical prostatectomy.

**Table 4**

Univariate Analysis of Risk Factors for Corneal Abrasion, 2009–2011

	Coding of the Variables (0 or 1, as labeled)	Prostatectomy*			Hysterectomy <sup>‡</sup>		
		OR	CI	P	OR	CI	P
Age	Continuous, increasing	1.01	0.99–1.04	0.362	1.03	1.02–1.04	0.0001
# of Chronic Conditions	Continuous, increasing	1.00	0.90–1.10	0.927	1.20	1.11–1.26	0.0001
Race	0 Caucasian; 1 African-American	0.06	0.01–0.44	0.005	0.19	0.09–0.42	0.0001
Year	Continuous, increasing	0.94	0.75–1.18	0.600	1.27	1.05–1.55	0.015
Malignancy	0 Benign; 1 Malignant	--	--	--	2.09	1.41–3.08	0.001
Robotic prostatectomy (R/Prost)	0 Prostatectomy, open; 1 R/Prost	1.55	1.01–2.36	0.043			
Modified hysterectomy	0 O/L/Hyst; 1 R/Hyst; 2 L/Hyst						
R/Hyst (1) vs O/Hyst (0)					7.78	5.23–11.57	0.0001
L/Hyst (2) vs O/Hyst (0)					3.69	2.52–5.41	0.0001

\* Open prostatectomy is the reference group;

<sup>‡</sup> Open hysterectomy is the reference group

Univariate analysis examined the impact of robotic surgery, laparoscopic surgery, age, race, chronic conditions, and calendar year of surgery as risk factors for CA in radical prostatectomy. For O/Hyst, L/Hyst and R/Hyst, we also included the presence of malignant disease. Race was coded as White or African American, as these were predominant in NIS. Description and coding of the terms appears in the 2<sup>nd</sup> column from the left. The terms from the univariate analysis with P < 0.2 were entered into the full model for multivariable analysis.

CA = corneal abrasion; CI = 95% confidence interval; L/Hyst = laparoscopic hysterectomy; NIS = Nationwide Inpatient Sample; O/Hyst = open hysterectomy; O/L/Hyst = open or laparoscopic hysterectomy; R/Hyst = robotic assisted laparoscopic hysterectomy; R/L/Hyst = robotic assisted or laparoscopic hysterectomy; R/Prost = robotic assisted laparoscopic radical.



**Table 5**

Multivariable Analysis of Risk Factors for Corneal Abrasion in 2009–2011

Reference	Covariate	Odds Ratio	95% confidence interval	Logistic Regression P-value	Hosmer and Lemeshow P-value	Area under ROC curve
Prostatectomy*	Robotic prostatectomy	1.508	0.987–2.302	0.057	0.9435	0.6003
	Race	0.062	0.009–0.446	0.006		
Hysterectomy <sup>‡</sup>	Modified hysterectomy	<i>R/Hyst</i> (1) vs <i>O/Hyst</i> (0)			0.6558	0.7850
		6.505	4.323–9.788	0.0001		
		<i>L/Hyst</i> (2) vs <i>O/Hyst</i> (0)				
		3.821	2.594–5.630	0.0001		
	Age	1.020	1.007–1.034	0.003		
	Malignant	1.031	0.657–1.618	0.895		
	# of chronic conditions	1.139	1.065–1.219	0.0001		
	Race	0.275	0.128–0.589	0.001		
	Year	1.119	0.916–1.368	0.271		

\* Open prostatectomy is the reference group;

<sup>‡</sup>Open hysterectomy is the reference group

The multivariable model, which considers all of the covariates (see Materials and Methods, Statistical Analysis subsection, paragraph 4, lines 1–5), used terms from the univariate model table 4 with  $P < 0.2$ . Results using either forward or backward elimination were the same. Among patients with prostatectomies, the risk of corneal abrasion was significantly less in African Americans compared to Whites. Among hysterectomy patients, robotic or laparoscopic procedure along with increasing age and number of chronic conditions was associated with higher risk for corneal abrasion; additionally, corneal abrasion was significantly less likely in African Americans compared to Whites. The Hosmer- Lemeshow and the area under the ROC curve values suggested good fit of the model.

ROC = receiver operating characteristic.