Corneal Abrasion in Hysterectomy and Prostatectomy

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 hysterectomy (L/HYST), has been increasingly frequently done *via* robot (R/HYST). Small case series suggest increased corneal abrasions (CAs) with less invasive techniques.

Methods: The authors identified RP (166,942), O/HYST (583,298), or L/HYST (216,890) discharges with CA in the Nationwide Inpatient Sample (2000–2011). For 2009–2011, they determined odds ratios (ORs) and 95% confidence intervals (CIs) for CA, in R/PROST, non-R/PROST, L/HYST, O/HYST, and R/HYST. Uni- and multivariate models studied CA risk depending on surgical procedure, age, race, year, chronic illness, and malignancy.

Results: In 2000–2011, 0.18% RP, 0.13% L/HYST, and 0.03% O/HYST sustained CA. Compared with 17,554 non-R/PROSTs (34 abrasions, 0.19%) in 2009–2011, OR was not significantly higher in 28,521 R/PROSTs (99, 0.35%; OR 1.508; CI 0.987 to 2.302; $P < 0.057$). CA significantly increased in L/HYST (70/51,323; 0.136%) *versus* O/HYST (70/191,199; 0.037%; OR 3.821; CI 2.594 to 5.630; $P < 0.0001$), further increasing in R/HYST (63/21, 213; 0.297%; OR 6.505; CI 4.323 to 9.788; $P < 0.0001$). For hysterectomy, risk of CA increased with age (OR 1.020; CI 1.007 to 1.034; $P < 0.003$) and number of chronic conditions (OR 1.139; CI 1.065 to 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/HYST or L/HYST.

Conclusions: L/HYST increased CA nearly four-fold, and R/HYST approximately 6.5-fold *versus* O/HYST. Identifiable preoperative factors are associated with either increased risk (age, chronic conditions) or decreased risk (race). **(ANESTHESIOLOGY 2015; 122:994-1001)**

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 postoperative analgesia compared with open prostatectomy (OP).[1]

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

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.[1] In a small study of 1,500 R/PROST patients, corneal abrasion (CA) was the most reported anesthesia-related complication (3%).[6] Because R/HYST and R/PROST share steep head down positioning, pneumoperitoneum, and a surgical learning curve, among other similarities, we hypothesized a similar incidence of eye-related complications.[7,8]

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 with open hysterectomy, risk of corneal abrasion was increased nearly four-fold with the laparoscopic technique and nearly 6.5-fold with the robotic technique

This article is featured in "This Month in Anesthesiology," page 1A. Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org). Dr. Sampat and Mr. Parakati contributed equally to this study. This work has been presented, in part, at the American Society of Anesthesiologists Annual Meeting 2012 in Washington, D.C., on October 16, 2012, and was accompanied by a press release and brief description of the findings.

Submitted for publication January 7, 2013. Accepted for publication January 28, 2015. From the Department of Neurology, Northwestern Memorial Hospital, Chicago, Illinois (A.S.); Department of Anesthesia and Critical Care (I.P., D.B.G., S.R.), Department of Obstetrics and Gynecology (N.K.L., M.T.), and Section of Urology, Department of Surgery (S.E.), The University of Chicago Medicine, Chicago, Illinois; and Department of Health Studies (R.K.) and The Center for Health and Social Sciences (S.R.), The University of Chicago, Chicago, Illinois.

 Anesthesiology 2015; 122:994-1001

We aimed to determine the incidence of CA after 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 *versus* 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.[9] CA is painful and disturbing and has been targeted for anesthesia performance improvement as potentially preventable.[10] With robotic-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, 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.*

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.† 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.‡ 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.§ 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, USA). 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 to 2011 were either OP or robotic assisted, with few identifiable as laparoscopic, without robotic assistance. Because the number of laparoscopic, non–robotic-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, whereas those that only had the procedure code for RP were classified as non-R/PROST, that is, OP (table 1 and fig. 1). L/HYST discharges that contained 17.42 or 17.44 codes were classified as R/HYST. Because 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

Table 1. ICD-9-CM Procedure Codes for Prostatectomy and 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.

* 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.

† HCUP Chronic Condition Indicator. Healthcare Cost and Utilization Project (HCUP). November 2011. Agency for Healthcare Research and Quality, Rockville, MD. Available at: www.hcup-us.ahrq.gov/toolssoftware/chronic/chronic.jsp. Accessed December 18, 2012.

‡ 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.

§ Whalen D, Houchens R, Elixhauser A. 2004 HCUP Nationwide Inpatient Sample (NIS) Comparison Report. HCUP Methods Series Report no. 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.

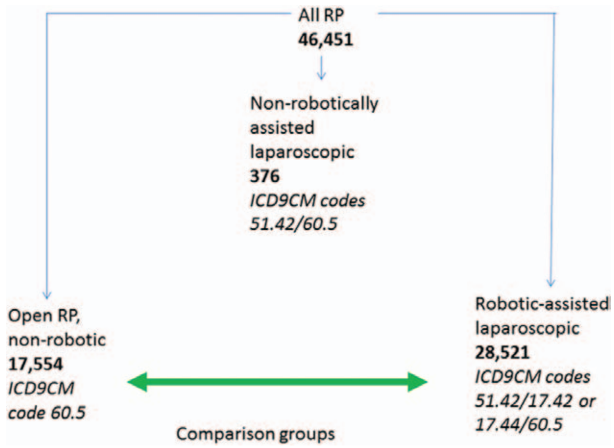

Fig. 1. Selection of discharges for radical prostatectomy. Radical prostatectomy (RP) discharges were segregated according to ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) codes. The ICD-9-CM codes and the number of discharges are shown. Because there were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

number needed to harm (NNH); also, we compared age, race, and number of chronic medical conditions between the groups, as we previously reported.[9] Odds ratios (ORs) were calculated by univariate and multivariate 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 *versus* nonmalignant 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, USA). 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* less than 0.05 significant. For R/HYST, L/HYST, and O/HYST, three-way comparisons used ANOVA with Bonferroni correction for three comparisons to compare mean age and mean number of chronic conditions; *P* less than 0.05 was significant. Chi-square analyses assessed race distributions and the presence of malignancy, and were corrected for multiple pairwise comparisons with *P* less than 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* less than 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* less than 0.05 were deemed significant, as were *P* values less than 0.05 for unpaired *t* tests and chi-square 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 greater than 0.5 and Hosmer and Lemeshow *P* greater than 0.05 were the thresholds for confirming the goodness of fit and validity of these models, respectively.

Results

The Overall Incidence of CA in RP and Hysterectomy

NIS contained 166,942 RP discharges from 2000 to 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 less than 10 discharges with CA (no more than 0.08%, 0.8 per thousand), whereas in 2011 there were 46 (0.28%, 2.8 per thousand), an increase of approximately three-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 to 2011, among 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 two-fold increase, in 2011 (table 2). The rate of CA in O/HYST remained stable during 2000–2011, an overall rate of 0.03%, or 0.3 per thousand (table 2).

Patient Characteristics and Incidence of CA in Laparoscopy and/or Robotic Assistance versus Open or Non–robotic-assisted Surgery

In 2009–2011, of 28,521 discharges with R/PROST, there were 99 CAs (3.5 per thousand); while 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

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
RP	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
Corneal abrasion	<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
L/HYST	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
Corneal abrasion	<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
O/HYST	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
Corneal abrasion	<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 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.

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 *versus* O/HYST and L/HYST and contained a lower proportion of African Americans compared with O/HYST (table 3). Moreover, L/HYST discharges were significantly younger, had lower average number of chronic conditions, had a lower proportion of African Americans, and had lower proportion of malignancy compared with O/HYST. R/HYST had significantly higher proportions of malignancy diagnoses compared with the other two groups. Among those discharges with CA, those who underwent R/HYST or L/HYST had fewer chronic conditions compared with 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 with L/HYST (table 3).

Univariate Analysis to Identify Risk Factors for CA

Univariate analysis (table 4) identified factors increasing risk for inclusion in multivariable analysis; terms with P less than 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% confidence interval [CI] 0.01 to 0.44, $P < 0.005$) while robotic use increased risk (OR 1.55, 95% CI 1.01 to 2.36, $P < 0.043$).

Robotic usage increased CA risk in hysterectomy (OR 7.78, 95% CI 5.23 to 11.57, $P < 0.0001$), as did laparoscopy (OR 3.69, 95% CI 2.52 to 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 CA 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 to 2.302, $P < 0.057$). However, being African American was a significant negative risk factor (OR 0.062, 95% CI 0.009 to 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 to 5.630,

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* Value (OP *vs.* R/PROST)	Robotic Hysterectomy (R/HYST)	Laparoscopic Hysterectomy (L/HYST)	Open Hysterectomy (O/HYST)*	*P* Value (Three-way Hysterectomy Comparisons, ANOVA)
All patients: number of discharges	17,554	28,521	—	21,123	51,323	191,199	—
Mean age: all patients (95% CI)	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
Average no. of chronic conditions: all patients (95% CI)	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
White (%): all	11,772 (76.3)	19,354 (77.3)	0.0001	13,367 (72.7)†	32,282 (72.5)†	104,476 (62.7)	0.0001
AA (%): all	2,047 (13.3)	2,772 (11.1)		2,014 (11.0)†	5,036 (11.3)†	30,434 (18.3)	
Benign (%)*: all				16,209 (76.7)†‡	48,332 (94.2)†	169,284 (88.5)	0.0001
Malignant (%): all				4,914 (23.3)†‡	2,991 (5.8)†	21,915 (11.5)	
CA patients (per 1,000)	34 (1.9/1,000)	99 (3.5/1,000)		63 (3.0/1,000)	70 (1.4/1,000)	70 (0.4/1,000)	
NNH for CA		652		382	1,002		
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 no. 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)	

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* value 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.

*Reference group; †$P < 0.001$ *vs.* O/HYST; ‡$P < 0.001$ *vs.* L/HYST; §$P < 0.013$ *vs.* O/HYST; ‖$P < 0.018$ *vs.* O/HYST.

CA = corneal abrasion; 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 to 2011

	Coding of the Variables (0 or 1, as Labeled)	Prostatectomy*			Hysterectomy†		
		OR	CI	*P Value*	OR	CI	*P* Value
Age	Continuous, increasing	1.01	0.99–1.04	0.362	1.03	1.02–1.04	0.0001
No. 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

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 appear in the second column from the left. The terms from the univariate analysis with $P < 0.2$ were entered into the full model for multivariable analysis.

*Open prostatectomy is the reference group. †Open hysterectomy is the reference group.

CA = corneal abrasion; 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 prostatectomy.

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†	Modified hysterectomy		R/HYST (1) *vs.* O/HYST (0)		0.6558	0.7850
		6.505	4.323–9.788	0.0001		
			L/HYST (2) *vs.* O/HYST (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		
	No. 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		

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 with 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; in addition, corneal abrasion was significantly less likely in African Americans compared with whites. The Hosmer–Lemeshow and the area under the ROC curve values suggested good fit of the model.

*Open prostatectomy is the reference group. †Open hysterectomy is the reference group.

O/HYST = open hysterectomy; R/ L/HYST = robotic-assisted or laparoscopic hysterectomy; ROC = receiver operating characteristic.

$P < 0.0001$), and in R/HYST, OR was 6.505 (95% CI 4.323 to 9.788, $P < 0.0001$; table 5). Additional factors that increased risk in hysterectomy included advancing age (OR 1.020, 95% CI 1.007 to 1.034, $P < 0.003$) and increasing number of chronic conditions (OR 1.139, 95% CI 1.065 to 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 Digital Content, table 1, http://links.lww.com/ALN/B140).

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.[11] Exposed corneas during general anesthesia had a significantly higher abrasion rate *versus* eyes that were covered, and a longer duration of operating time, that is, greater corneal exposure, increased the rate, with the peak incidence occurring between 90 and 150 min.[12] The latter study, however, was performed approximately 40 yr 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.[13]

Another potential mechanism of injury in RP and hysterectomy is the increase in intraocular pressure (IOP) in steep Trendelenburg position during R/PROST,[14] L/HYST, and R/HYST. Surgeons request such positioning for surgical exposure and optimal robotic arm positioning. But high head down angles (40° to 45°) may not actually be necessary.[15] Corneal or conjunctival edema may also occur from increased central venous pressure[16] 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.[17]

About 80% of RPs have robotic assistance.[18] As a result of rapid introduction of the robot, there were few cases in NIS of laparoscopy alone (fig. 1). Hence, our comparison was exclusive of OP to robotic-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.[19] Xian *et al.*,[20] for example, noted that African Americans had lower mortality than whites. Also, African Americans greater than 65 yr had lower adjusted 30-day mortality than whites after congestive heart failure, acute myocardial infarction, hip fracture, and gastrointestinal bleeding, which suggests a systemic *versus* disease-specific effect.[21,22] 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.[9] 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 one-fourth of the L/HYST and RP cases in 2009–2011 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.[18] 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 to 2011 for RP and hysterectomy. In 2009–2011, there was an approximately four times higher risk when laparoscopy was used for hysterectomy, and a seven times higher risk when L/HYST was robotically assisted, compared with 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,[23] 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.

Acknowledgments

At the time this study was conducted, Dr. Sampat was a medical student at the Pritzker School of Medicine, The University of Chicago, Chicago, Illinois. Dr. Sampat was the recipient of the Calvin Fentress Medical Student Research Scholarship (Chicago, Illinois), which provided partial funding for the study. Additional funding was provided by departmental sources and by National Institutes of Health (Bethesda, Maryland) Grant RO1 EY10343 to Dr. Roth, and by a grant from the National Institutes of Health to the University of Chicago Institute for Translational Medicine (UL1 RR024999).

Competing Interests

Dr. Roth has served as an expert witness in cases of perioperative eye injuries on behalf of patients, physicians, and hospitals. The remaining authors declare no competing interests.

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