RALRP is the procedure of choice when treating localized prostate cancer.

Robotic-Assisted Laparoscopic Radical Prostatectomy

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**Background:** The use of radical prostatectomy for the treatment of prostate cancer has been increasing during the last decade partially due to the widespread adoption of the robotic-assisted laparoscopic technique. Although no prospective, randomized controlled trials have compared open radical prostatectomy (ORP) with robotic-assisted laparoscopic radical prostatectomy (RALRP), numerous comparative studies have been retrospectively conducted.

**Methods:** A systematic review of the literature was performed to clarify the role and advancement of RALRP. Studies comparing ORP with RALRP that measured outcomes of cancer control, urinary and sexual function, and complications were included. A nonsystematic review was utilized to describe the advancements in the techniques used for RALRP.

**Results:** RALRP is the procedure of choice when treating localized prostate cancer. This preference is due to the observed improvement in morbidity rates, as evidenced by decreased rates of blood loss and postoperative pain and similar oncological outcomes when compared with ORP. Robotic assistance during surgery is continually being modified and the techniques advanced, as evidenced by improved nerve sparing for preserving potency and reconstruction of the bladder neck to help in the early recovery of urinary continence.

**Conclusions:** Morbidity rates should continue to improve with the advancement of minimally invasive techniques for radical prostatectomy. The adoption of robotic assistance during surgery will continue as the applications of robotic-assisted surgery expand into other solid organ malignancies.

**Introduction**

Prostate cancer is the second leading cancer-related cause of death for men in the United States. In 2015, approximately 220,800 American men will be diagnosed with prostate cancer and 27,540 will die from their disease. The majority of men will present with localized disease (81%) for which multiple options for treatment exist, including radical prostatectomy, external beam radiation, brachytherapy, and active surveillance, among other less well-studied treatments. During the last decade, the use of radical prostatectomy for the treatment of prostate cancer has increased, partially due to the adoption of minimally invasive surgical techniques that utilize robotic assistance.

Since the first published account of surgical treatment for prostate cancer by Young in 1905, in which he described perineal prostatectomy, the disease process and goals for outcomes have changed. Walsh and Donker helped to modernize the retropubic approach to include nerve sparing and preserving the external urethral sphincter to aid in potency and the maintenance of urinary continence after surgery. In 1997, Schuessler et al described the first laparoscopic radical prostatectomy, but the procedure was not widely adopted because of the higher level of difficulty and advanced laparoscopic skills needed to perform the
technique. However, despite the lack of widespread adoption, some centers of excellence exist where pure laparoscopic radical prostatectomies are performed.

To continue to incorporate the expected advantages of minimally invasive surgery into a broader base of urologic surgeons, the robotic-assisted laparoscopic radical prostatectomy (RALRP) technique was adopted, and Menon et al. performed the first of this procedure in the United States in 2000. Fifteen years later, RALRP is now the procedure of choice in the United States for the treatment of localized prostate cancer. More than 80% of prostatectomies are performed this way.7

**Methods**

We reviewed PubMed and the Cochrane Library for English-language studies that compared RALRP and open radical prostatectomy (ORP) in men with prostate cancer using the search terms “prostatectomy” and “comparison.” We then screened 646 studies for reported outcomes of cancer control, sexual and urinary function, and complication rate. We then further narrowed our search by excluding studies that did not directly compare ORP with RALRP and had fewer than 500 patients (Fig).

No randomized controlled trials met our inclusion criteria. We included observational studies comparing ORP and RALRP in prospective, retrospective, and population studies. Two independent reviewers (GA and AML) selected the studies. The information presented on modified surgical techniques has been selected separate from the systematic review.

Of the 19 observational studies we identified and included in our review, 5 were prospective and 14 were retrospective.

**Indications**

**Typical Candidates**

Any patient with localized prostate cancer who is a candidate for open surgery is also a candidate for robotic-assisted surgery. A typical patient has T1 or T2 disease with no evidence of metastatic spread, and, similar to candidates for open surgery, the patient would be expected to have a life expectancy of more than 10 years. Patients with T3 or T4 disease should be considered for open or robotic-assisted surgery as well as those with oligometastasis in the pelvic lymph nodes (LN). Surgery should be part of a multimodal approach to disease management in such patients.

**Salvage Surgery**

Patients who undergo primary treatment for localized prostate cancer with brachytherapy or external beam radiation therapy and have local recurrence within the prostate confirmed by biopsy are eligible for salvage treatment. These treatments vary in their rates of efficacy and include androgen deprivation therapy, cryoablation of the prostate, and salvage radical prostatectomy. With regard to long-term cure after salvage treatment for localized prostate cancer recurrence, salvage radical prostatectomy alone has been demonstrated to have more than 10 years of cancer control in a large proportion of patients.8

The improved magnification afforded by the laparoscopic camera is a potential benefit of the robotic technique for salvage prostatectomy because a major complication following the procedure is rectal injury as a result of the posterior dissection of the prostate. The number of overall complications encountered highlights the rate of morbidity associated with the procedure. In a review of 51 consecutive surgical candidates who underwent salvage RALRP for recurrent prostate cancer following primary radiation therapy, an overall complication rate of 47% was seen and included 2 rectal injuries; 23% of the study volunteers remained potent and 45% remained continent following treatment.9 A total of 57% of patients remained free of biochemical recurrence at 3 years.9 Thus, salvage surgery remains feasible; however, it should be attempted at high-volume centers alone.

**Selected Contraindications**

Comorbid conditions, such as chronic obstructive pulmonary disease, may disqualify a patient from robotic-assisted surgery because he or she will be in an extreme Trendelenburg position for 3 to 4 hours and pneumoperitoneum may be present with carbon dioxide, possibly resulting in hypercapnia and difficulties with ventilation. A patient with a bleeding diathesis would also not be a candidate for either robotic-assisted or laparoscopic surgery.

**Surgical Techniques**

**Extraperitoneal vs Transperitoneal Approach**

Consistent with traditional open retropubic radical prostatectomy, the extraperitoneal approach to RALRP provides the surgeon with familiar anatomy and dis-
section planes that can be assimilated with ease. Theoretical advantages to the extraperitoneal approach include the avoidance of peritoneal contents that can enter into the field of interest and cause injury to the bowel, decreased postoperative ileus, and containment of postoperative urine leaks, lymphoceles, and abscesses. In addition, avoiding adhesions by remaining in the retropubic space is advantageous in patients with a history of previous abdominal operations.

The most common approach is transperitoneal, which provides a wider space to work in and allows the surgeon to perform an extended pelvic LN dissection and posterior dissection of the prostate and seminal vesicles. In a study by Davis et al, no observed differences were seen between extraperitoneal and transperitoneal RALRP with regard to length of hospital stay, complications, and positive surgical margins. Chung et al found similar rates of positive surgical margins, potency, and urinary continence between the 2 techniques but a decreased incidence of bowel complications and postoperative pain in the extraperitoneal group. However, the surgeon’s experience with a particular technique is the factor with the greatest effect on patient outcomes.

Anterior vs Posterior Approach
Two widely utilized approaches to dissection of the posterior prostate and seminal vesicles involve an anterior approach in which the bladder neck is opened and a posterior approach in which the plane between the rectum and posterior prostate is developed. The posterior approach is performed with a transperitoneal method alone, whereas the anterior approach can be achieved with both transperitoneal and extraperitoneal techniques. Using the posterior approach, the surgeon has direct access to the seminal vesicles and can develop the posterior plane between the prostate and the rectum to the distal extent of the apex of the prostate. Doing so allows for the dissection of the seminal vesicles in a relatively open space compared with what can sometimes be a challenging small hole encountered in the anterior approach. The posterior approach also helps the surgeon desiring to perform robotic-assisted radical cystectomies familiarity with the technique. However, preserving the neurovascular bundles as they come into proximity with the seminal vesicles can be more readily achieved with the anterior approach. Maddox et al found no differences in positive surgical margins, blood transfusions, operative times, and complication rates between the anterior and posterior approaches to RALRP.

Preservation of the Neurovascular Bundles
The morbidity from anatomic radical prostatectomy, a curative treatment for prostate cancer, has been declining. The neurovascular bundles are posterolaterally located on the prostate and contain parasympathetic and sympathetic nerve fibers. Walsh and Donker initially presented their results in 1982, using the anatomical dissection of male newborns and fetuses to map the autonomic innervation of the corpora cavernosa responsible for erectile function. In their paper, the area of the pelvic plexus of nerves was most susceptible to injury during dissection of the apex and ligation of the lateral pedicles to the prostate. Also reported in that manuscript were the primary predictors of postoperative potency, including age and stage of disease. Men younger than 60 years of age and with cancer confined to the prostate capsule have a potency rate that nears 60%.

Since the first report in 1982, and with the increased magnification afforded by the laparoscopic camera utilized in RALRP, the nerves can be better visualized for preservation. In a retrospective cohort of 435 study patients who underwent nerve-sparing radical prostatectomy, Briganti et al categorized patients into groups of low, intermediate, and high risk for postoperative erectile dysfunction and determined the classification system used to predict erectile function recovery. The low-risk group was composed of study patients younger than 65 years of age, those with an International Index of Erectile Function score higher than 26, and a Charlson Comorbidity Index below 1; those in the high-risk group were composed of study patients older than 70 years, those with an International Index of Erectile Function below 10, and those with a Charlson Comorbidity Index above 2. In total, 89% of those in the low-risk group recovered erectile function compared with 37% in the high-risk group.

Furthermore, Gandaglia et al compared the open and robotic-assisted approaches to nerve-sparing radical prostatectomy and found that study patients in the low- and intermediate-risk classification of erectile function benefited the most from robotic-assisted surgery when looking at postoperative recovery rates, whereas no significant difference was seen between the open and robotic-assisted procedure in the high-risk cohort.

These studies helped determine which patients may benefit from a nerve-sparing procedure and for physicians to provide a better expectation to their patients about the surgical results. Patients with high-grade and high-volume disease seen on prostate biopsy are more likely to harbor extraprostatic disease and, thus, have an increase likelihood of experiencing positive surgical margins during a nerve-sparing procedure, resulting in poor cancer control.

Some advocate the preoperative use of magnetic resonance imaging (MRI) in such higher-risk patients to determine the extent of cancer and whether unilateral or bilateral nerve sparing can be performed. For example, Park et al reviewed 355 patients who obtained preoperative MRI followed by RALRP and
found that the initial surgical plan was changed in 26% of patients following MRI. Of those patients whose surgical plans changed, 57% were changed to a plan to preserve their neurovascular bundles, and 43% were changed to a more aggressive resection of their nerves with the prostate. In high-risk prostate cancer groups, MRI had a 80% sensitivity rate for detecting extracapsular extension of disease. Rifaoglu et al performed a deceased donor study in which they performed prostatectomy with intrafascial and interfascial nerve-sparing techniques. They examined the tissue surrounding the prostate and found that, compared with deceased donors with intrafascial nerve sparing, deceased donors with intrafascial nerve sparing had a greater amount of sympathetic fibers present in the neurovascular bundles without an increase in prostate capsular penetration. Thus, the degrees of nerve sparing can vary depending on the technique used. A large-volume comparison of retrograde and antegrade nerve-sparing techniques was conducted and the retrograde technique was shown to have an earlier recovery of potency; however, at 1 year, the potency rates were about the same between the 2 techniques.

**Seminal Vesicle Sparing**

Included in the procedure for radical prostatectomy is en bloc resection of the seminal vesicles because they are related to the prostate and, depending on the disease risk group, may harbor disease. Huang et al reviewed 7,376 patients receiving radical prostatectomy and found that those with low-risk disease have a risk of less than 2% for harboring cancer in their seminal vesicles. This risk increased with the presence of higher risk features such as a Gleason score of 7 to 10 and a prostate-specific antigen value higher than 10.

Due to the close proximity of the neurovascular bundles to the seminal vesicles, theoretically a seminal vesicle sparing approach could be performed in low-risk patients to aid in the postoperative recovery of erectile function. Sanda et al measured the effect of seminal vesicle sparing during open radical prostatectomy on the recovery of erectile function in 191 study patients and found improved sexual health among those with the tips of the seminal vesicle left in situ. However, the results of seminal vesicle sparing must be prospectively validated in a larger cohort of patients before definitive conclusions can be made regarding this technique.

**Posterior Reconstruction**

Following the extirpation of the prostate, the surgeon must reconstruct the lower urinary system by anastomosing the bladder neck to the urethra. In 2001, Rocco et al described a modification to conventional urethrovessical anastomosis by adding a step prior to this that involved restoring the posterior aspect of the rhabdosphincter. The technique involves bringing the posterior sphincter to the residual Denovilliers fascia and posterior bladder wall. In the initial series performed in study patients undergoing radical retropubic prostatectomies, the urinary incontinence rates were significantly improved in those undergoing the “Rocco” stitch (at 90 days, the rates were 86.3% in the posterior reconstruction group and 46% in the traditional group). The primary difference was seen in time to continence; at 1 year, both groups had a 90% continence rate. However, in 2 randomized trials comparing study patients who received RALRP with and without posterior reconstruction, no significant difference was seen in early return of continence following catheter removal between either of the 2 groups.

**Lymph Node Dissection**

The presence of LN metastasis in patients with prostate cancer portends a poor prognosis. Patients who harbor high-volume and high-grade disease are more likely to have LN metastasis present, whereas low-risk patients with prostate cancer undergoing LN dissection have a 1% rate of metastasis to the LNs.

Utilizing any of the several available nomograms to predict the extent of disease at the time of radical prostatectomy makes it possible to determine which patients are likely to benefit from LN dissection at the time of surgery. A patient at risk of LN metastasis higher than 2% by nomogram should be considered for LN dissection. Standard LN dissection includes the obturator and the internal and external iliac nodes. One of the most common landing sites for LN metastasis are the internal iliac nodes in which up to 50% of positive nodes in a large series were found. Briganti et al demonstrated an improved detection rate as the number of nodes removed increased, and they advocated for an extended LN dissection in all high-risk patients. When fewer than 10 nodes were removed, the researchers detected nearly no LN metastasis; however, when more than 30 nodes were sampled, their rate of detection was close to 100%.

The number of nodes is not a marker of adequate lymphadenectomy because variability exists in this number and it depends on the sampling technique used by the pathologist. At this time, no randomized trials have demonstrated any benefit from lymphadenectomy in patients with prostate cancer. Diagnostic and therapeutic benefits may potentially exist following LN dissection; however, the procedure does have risks, including postoperative lymphocele, lymphedema, bleeding, and deep venous thrombosis; total complication rates are as high as 10% in some series.

Whether LN dissection is performed or not during minimally invasive prostatectomy depends on the preference of the surgeon and has not been demonstrated to have an effect on the complication rate. In a
Pelvic Drain Placement
Following RALRP with or without pelvic LN dissection, placement of a pelvic drain to collect urine and lymph fluid and to detect any postoperative bleeding is a standard approach. Retrospective reviews have been performed to compare patients who did not receive a pelvic drain, because omitting this step has been theorized to aid in early postoperative discharge rates and decreased pain.29 The conclusions from the authors of these studies is that when a properly visualized urethrovesical anastomosis is performed, omitting the pelvic drain is safe and does not result in increased complications.29 However, the benefit from omitting the pelvic drain has not been demonstrated; thus, the diagnostic information received from recognition of a postoperative bleed, large urine, or lymph leak provide justification for its continued use, so it is still employed in our practice.

Bladder Drainage
Similar to drain placement, urethral catheter drainage following RALRP has been the standard method of bladder drainage for the majority of institutions performing this procedure. Among 184 male study patients undergoing radical prostatectomy, 45% of them reported that the urethral catheter was moderately to severely bothersome and 19% said it caused pain at the incision site.30 Given these findings, the early removal of urethral catheters is of interest to most surgeons. The length of catheterization varies by institution between 2 to 7 days.31

Other methods to potentially help reduce bother include the placement of a suprapubic tube at the time of prostatectomy and removal of the urethral catheter on postoperative day 1. In a randomized trial comparing early removal and placement of a suprapubic tube with traditional urethral catheter removal on postoperative day 7, no differences were seen in bother and treatment satisfaction between the 2 groups.32

Complications
When analyzing complications related to RALRP, a dichotomized approach is preferable in which perioperative short-term outcomes and functional effects are assessed. Short-term complications include those related to any major abdominal operation and include infection, lymphocele, deep venous thrombosis, urine leak, ileus, and bleeding. Long-term complications include impotence, urinary incontinence, penile shortening, and bladder neck contracture. Refer to Table 1 for a review of complications in the studies comparing RALRP and ORP.33–37

Agarwal et al38 reported on 3,317 consecutive study patients who underwent RALRP at a single institution between 2005 and 2009 and found an overall complication rate of 10%. The majority of complications occurred within 30 days.38 A total of 2.1% of patients received a perioperative blood transfusion, 2% had postoperative bleeding, 1% had urine leaks, and 0.3% had venous thromboembolism.38 Nine study patients also had enterotomies during surgery that required repair.38 These findings were confirmed in a recent meta-analysis by Novara et al39; the rates of blood loss and transfusions alone were significantly different between the RALRP and ORP groups, although the groups undergoing RALRP had lower values in both categories. Thus, the robotic approach to prostatectomy is a safe procedure with acceptable rates of morbidity.

Potency
Loss of erectile function is a known complication of radical prostatectomy, and extensive research into the cause, preservation, and treatment of this loss of function has been performed. The pelvic parasympathetic nerves responsible for erectile function are involved with the anatomy of the prostate, and preserving these neurovascular bundles has a beneficial impact in maintaining potency following prostatectomy; however, other factors, such as age and stage of disease, continue to have a major impact. Recovery of function utilizing phosphodiesterase (PDE) inhibitors is effective. No difference has been seen in daily PDE inhibitor use and on-demand use in recovery; however, significantly reduced function has been shown in those naive to PDE inhibitors.40 Thus, in any potency preservation program, early use of PDE inhibitors should be encouraged because their use may reduce corporal fibro-
sis and prevent penile shortening, an under-reported complication.41 It is worth noting that it is important to include these sexual adverse events when counseling patients wishing to undergo the procedure.

In a review of more than 3,000 study patients who underwent RALRP between 2008 and 2011 by surgeons who had performed at least 100 cases, the potency rate at 1 year was as high as 90% in some instances.42 However, the results from this study are retrospective, have no standardized reporting methods, and the study patients had differing clinicopathologic characteristics.42 See Table 2 for a review of erectile function in studies comparing RALRP and ORP.35-36,43-47

**Continence**

Similar to the preservation of potency, maintaining continence following prostatectomy is a major cause of patient dissatisfaction following surgery. After removal of the prostate, the internal sphincter is no longer present, so patients must rely on their external sphincter for urinary control. By preserving the bladder neck and using modifications, such as the posterior reconstruction of the sphincter, improved rates of continence can be achieved and can reach nearly 90% in most reported series.48 By preserving the neurovascular bundle, it may be possible to improve continence following prostatectomy.49 Similar to potency, maintaining continence following prostatectomy depends on the surgery and the patient’s clinicopathological characteristics, such as age, preoperative urinary control, and pathological stage of disease. See Table 3 for a review of continence rates in studies comparing RALP and ORP.

**Cancer Control**

The most important outcome for patients undergoing RALRP is the presence of negative surgical margins and the removal of all prostatic disease. The positive margin rate increases with grade and stage of disease on preoperative prostate biopsy with overall rates of 27%, and, when stratified by the National Comprehensive Cancer Network, rates were 19% for low, 26% for intermediate, and 40% for high-risk prostate cancer groups.50

If pathology results from the final prostatectomy specimen demonstrate positive margins, seminal vesicle invasion, or extracapsular extension, then these patients are generally counseled to receive adjuvant external beam radiation, because results from randomized controlled trials have demonstrated improved metastasis and biochemical-free survival rates for those receiving adjuvant compared with salvage radiation.50,51 No randomized controlled trial has compared RALRP with open prostatectomy, so conclusions are difficult to make regarding which approach will yield improved rates of cancer control; however, an important factor that improves outcomes is undergoing surgery at a high-volume center (> 10 prostatectomies/year).50 See Table 4 for a review of positive surgical margin rates in studies comparing RALRP and ORP.35,36,43-46

Future Advancements

Adopting advanced technologies into the treatment armamentarium of the urological surgeon must be rapid and continuous, and well-designed clinical

### Table 2. — Urinary Function for ORP and RALRP

<table>
<thead>
<tr>
<th>Study</th>
<th>Urinary Continence, n (%)</th>
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<tbody>
<tr>
<td></td>
<td>ORP</td>
</tr>
<tr>
<td>Hu et al.58</td>
<td>6,889 (11.9)</td>
</tr>
<tr>
<td>Krambeck et al.59</td>
<td>588 (88)</td>
</tr>
<tr>
<td>Barry et al.55</td>
<td>220 (8.9)</td>
</tr>
<tr>
<td>Kim et al.56</td>
<td>235 (85)</td>
</tr>
<tr>
<td>Alemozaffar et al.57</td>
<td>621 (74.4)</td>
</tr>
<tr>
<td>Malcolm et al.58</td>
<td>135 (79)</td>
</tr>
<tr>
<td>Lowrance et al.59</td>
<td>3,760 (5)</td>
</tr>
</tbody>
</table>

*Urinary function as reported in Medicare coding for incontinence.
*Continence as no pads.
*Urinary function reported as being a “big problem” on questionnaire.
*Continence described as being completely pad free.
*Urinalysis based on EPIC-26 score reporting continence.
*Continence reported on a health-related, quality-of-life urinary function questionnaire.
*Incontinence requiring a procedure.
*P < .01.

ORP = open radical prostatectomy, RALRP = robotic-assisted laparoscopic radical prostatectomy.

### Table 3. — Rates of Positive Surgical Margins for ORP and RALRP

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<tr>
<td>Silberstein et al.52</td>
<td>961 (15)</td>
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<tr>
<td>Koo et al.53</td>
<td>580 (21.8)</td>
</tr>
<tr>
<td>Hu et al.54</td>
<td>5,524</td>
</tr>
<tr>
<td>Low, %</td>
<td>9.2</td>
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<td>Intermediate, %</td>
<td>21</td>
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<tr>
<td>High, %</td>
<td>21</td>
</tr>
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<td>Pierorazio et al.55</td>
<td>743 (29.4)</td>
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<tr>
<td>Park et al.56</td>
<td>277 (21)</td>
</tr>
<tr>
<td>Vora et al.57</td>
<td>415</td>
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<tr>
<td>pT3, %</td>
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trials must be developed to test the safety and efficacy of these new techniques. The ability to better detect and preserve the neurovascular bundles involved with preserving potency using bioluminescence and sound amplification from nerve sensors as well as enhanced microscopic visualization are on the horizon. The ability of the robot to provide haptic feedback to the surgeon will allow for improved tissue discrimination, possibly reducing traction injury on the neurovascular bundles and tissue trauma. Currently, modifications of the robotic-assisted approach to prostatectomy are being performed that involve a transition to a laparoscopic single site. The future of prostate surgery is exciting and emphasizes patient-centered outcomes. It is our hope that robotic-assisted surgery will help reduce mortality rates from prostate cancer and morbidity rates related to treatment.

Conclusions
The diagnosis and treatment of prostate cancer have evolved during the last 20 years. The adoption of robotic-assisted laparoscopic radical prostatectomy has not been unequivocally shown to be superior to the open approach. However, continual technical advancements of prostatectomy will translate into improved patient outcomes.

Table 4. — Sexual Function for ORP and RALRP

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<td>Krambeck28,29</td>
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<tr>
<td>Barry30,31</td>
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<tr>
<td>Kim et al32,33</td>
<td>235 (47.5)</td>
</tr>
<tr>
<td>Alemezaffar34,35</td>
<td>621 (36.8)</td>
</tr>
<tr>
<td>Malcolm36,37</td>
<td>135 (84)</td>
</tr>
</tbody>
</table>

*Percentage reporting being impotent in Medicare coding.

1Sexual function based on potency at 1 year on a nonvalidated questionnaire.

2Sexual function reported as being a "big problem" on questionnaire.

3Sexual function reported as erection sufficient for penetration at 2 years; 34% in the ORP group received a bilateral nerve sparing procedure compared with 53% in the RALRP group.

4Sexual function based on the Expanded Prostate Cancer Index Composite 26-item score (reporting impotence).

5Health-related, quality-of-life sexual function questionnaire documenting potency.

6P < .01.

ORP = open radical prostatectomy, RALRP = robotic-assisted laparoscopic radical prostatectomy.

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3. Young HJ. The early diagnosis and radical cure of carcinoma of the prostate. Being a study of 40 cases and presentation of a radical operation which was carried out in four cases. 1905. J Urol. 2002;168(3):914-921.
26. Briganti A, Karakiewicz P, Chun FK, et al. Percentage of positive biopsy cores can improve the ability to predict lymph node invasion in pa-