Pretreatment Nomogram for Prostate-Specific Antigen Recurrence After Radical Prostatectomy or External-Beam Radiation Therapy for Clinically Localized Prostate Cancer


Purpose: To present nomograms providing estimates of prostate-specific antigen (PSA) failure-free survival after radical prostatectomy (RP) or external-beam radiation therapy (RT) for men diagnosed during the PSA era with clinically localized disease.

Patients and Methods: A Cox regression multivariable analysis was used to determine the prognostic significance of the pretreatment PSA level, 1992 American Joint Committee on Cancer (AJCC) clinical stage, and biopsy Gleason score in predicting the time to posttherapy PSA failure in 1,654 men with T1c2 prostate cancer managed with either RP or RT. Pretreatment PSA, AJCC clinical stage, and biopsy Gleason score were independent predictors (P < .0001) of time to posttherapy PSA failure in patients managed with either RP or RT. Two-year PSA failure rates derived from the Cox regression model and bootstrap estimates of the 95% confidence intervals are presented in the format of a nomogram stratified by the pretreatment PSA, AJCC clinical stage, biopsy Gleason score, and local treatment modality.

Conclusion: Men at high risk (≥ 50%) for early (< 2 years) PSA failure could be identified on the basis of the type of local therapy received and the clinical information obtained as part of the routine work-up for localized prostate cancer. Selection of these men for trials evaluating adjuvant systemic and improved local therapies may be justified.

Recommendations for the Treatment of Clinically Localized Adenocarcinoma of the Prostate: The ideal end point on which to make therapeutic decisions is survival. At present, follow-up is too short to make statistically meaningful statements regarding survival for men diagnosed and treated for clinically localized disease in the prostate-specific antigen (PSA) era as a function of the pretreatment prognostic factors and treatment modality. However, pretreatment prognostic factors have established roles in predicting recurrence (PSA, clinical) after radical prostatectomy (RP) or external-beam radiation therapy (RT). These pretreatment factors include the PSA, the biopsy Gleason score, and the 1992 American Joint Committee on Cancer (AJCC) clinical stage.

Using these three factors, Partin and colleagues have compiled tables predicting the probability of organ-confined, focal and extracapsular extension, seminal vesicle invasion, and lymph node disease using a pooled database of 4,133 patients acquired between April 1982 and June 1996. Although their system is useful, it has become increasingly apparent that not all patients with pathologic organ-confined disease remain without PSA failure, particularly if their preoperative PSA was greater than 10 ng/mL or the biopsy Gleason score was at least 7. Moreover, not all patients with established extracapsular extension or seminal vesicle invasion fail biochemically within 5 years postoperatively. Therefore, in an attempt to approximate more closely the clinically relevant end point of survival, the reporting of PSA failure–free survival has been used. Specifically, Kattan and colleagues have established a nomogram based on the pretreatment PSA, biopsy Gleason score, and 1992 AJCC clinical stage to predict PSA failure–free survival postoperatively. In addition, D’Amico and colleagues have performed a similar analysis using the preoperative PSA, pathologic stage, margin status, and prostatectomy Gleason score to predict postoperative PSA failure–free survival.

In this report, nomograms have been derived expressing 2-year PSA failure rates with 95% confidence intervals as a function of the pretreatment PSA, biopsy Gleason score, and AJCC clinical stage for patients undergoing either RP or RT. The time point of 2 years was chosen in an attempt to identify patients with early PSA failure. Patients with early PSA failure have been previously shown to present with distant failure as their most common site of first failure, and therefore, they are more likely to harbor occult micro-
metastatic disease at the time of local therapy. Although metastatic prostate cancer currently is not a curable disease, the finding of early PSA failure, given time, is likely to translate into a decrement in cause-specific and overall survival.

PATIENTS AND METHODS

Patient Population

Eight hundred ninety-two men treated with a radical retropubic prostatectomy and bilateral pelvic lymph node dissection at the Hospital of the University of Pennsylvania (PENN) and 762 men given external-beam RT at the Joint Center for Radiation Therapy (JCRT) between 1989 and 1997 and who had PSA-detected and/or clinically palpable disease comprised the study population. Table 1 lists the pretreatment characteristics of the 1,654 study patients stratified by the type of local therapy.

Pretreatment Staging

Staging evaluation included a history and physical examination, including a digital rectal examination (DRE), determination of serum PSA level, computed tomography of the pelvis or an endorectal and pelvic coil magnetic resonance imaging (MRI) scan of the prostate and seminal vesicles, a bone scan, and a transrectal ultrasound-guided needle biopsy of the prostate, with Gleason score histologic grading. A sextant biopsy was performed by means of an 18-gauge Tru-Cut needle (Travenol Laboratories, Deerfield, IL) via a transrectal approach. The clinical stage was determined from the DRE findings according to the AJCC staging system. Radiologic and biopsy information was not used to determine the clinical stage. The PSA was obtained on an ambulatory basis before radiologic studies and biopsy were performed. All PSA measurements were made using the Hybritech, Tosoh, or Abbots assay.

Treatment

A referee genitourinary pathologist reviewed the diagnostic biopsy specimens for all patients undergoing RP at PENN (J.E.T.) or RT at JCRT (A.A.R.). Surgical treatment consisted of a radical retropubic prostatectomy and bilateral pelvic lymph node sampling.

Table 1. Clinical Characteristics of the Surgically Managed Patients at PENN and Radiation-Managed Patients at JCRT

<table>
<thead>
<tr>
<th>Clinical Characteristic</th>
<th>PENN (n = 892)</th>
<th>JCRT (n = 762)</th>
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<tr>
<td>Clinical stage</td>
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<tr>
<td>T1c</td>
<td>259 (29%)</td>
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<td>T2a</td>
<td>392 (44%)</td>
<td>244 (32%)</td>
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<td>T2b</td>
<td>89 (10%)</td>
<td>145 (19%)</td>
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<tr>
<td>T2c</td>
<td>152 (17%)</td>
<td>152 (20%)</td>
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<td>PSA (ng/mL)</td>
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<tr>
<td>0-4.0</td>
<td>89 (10%)</td>
<td>76 (10%)</td>
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<td>4.1-10.0</td>
<td>509 (57%)</td>
<td>328 (43%)</td>
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<td>10.1-20.0</td>
<td>214 (24%)</td>
<td>198 (26%)</td>
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<tr>
<td>20.1-50.0</td>
<td>80 (9%)</td>
<td>160 (21%)</td>
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<tr>
<td>Biopsy Gleason score</td>
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<tr>
<td>2-4</td>
<td>170 (19%)</td>
<td>106 (14%)</td>
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<td>5-6</td>
<td>517 (58%)</td>
<td>381 (50%)</td>
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<td>7</td>
<td>134 (15%)</td>
<td>191 (25%)</td>
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<tr>
<td>8-10</td>
<td>71 (8%)</td>
<td>84 (11%)</td>
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</table>

All patients managed with definitive RT were treated using at least 10 MV photons and a conformal shaped four-field technique. Those patients with AJCC clinical stage T1c,2a disease who also had a PSA of less than 10 ng/mL and a biopsy Gleason score of 2 to 6 were treated to the prostate only with a 1.5-cm margin. The median prescription dose was 66 Gy (range, 66 to 70 Gy) and was delivered using 2-Gy fractions. All other patients with clinically localized disease received a median prescription dose of 45 Gy (range, 45 to 50.4 Gy) in 1.8-Gy fractions to the prostate and seminal vesicles plus a 1.5-cm margin. This was followed by treatment to the prostate alone using a shrinking field technique with a 1.5-cm margin to a median prescription dose of 22 Gy (range, 18 to 22 Gy) in 1.8- to 2.0-Gy fractions. A 95% normalization was used routinely.

Follow-Up

The median follow-up for the 892 surgically managed and 762 radiation-managed patients was 42 months (range, 9 to 94 months) and 38 months (range, 8 to 75 months), respectively. The patients were seen 1 month postoperatively, then at 3-month intervals for 2 years, every 6 months for 5 years, and annually thereafter. At each follow-up examination, a serum PSA sample was obtained before the DRE was performed. All baseline PSA values were obtained within 1 month of the date of surgery or start of radiation therapy. No patient was lost to follow-up, and all patients were alive at the time of analysis. No patient received adjuvant or neo-adjuvant hormonal or radiation therapy before PSA failure, which was the primary end point in this study.

Statistical Analysis

A Cox regression time to PSA failure analysis evaluating the ability of the pretreatment PSA, biopsy Gleason score, and AJCC clinical stage to predict time to posttherapy PSA failure was performed separately for all RP- and RT-managed patients. The assumptions of the Cox model were tested and met. The pretreatment PSA was treated as a continuous variable. The biopsy Gleason score was treated as a continuous variable that could have integer values from 2 to 10 inclusive. The AJCC clinical stage was treated as a categorical variable with values of T1c, T2a, T2b, or T2c. PSA failure was defined as the occurrence of three consecutive increasing posttherapy PSA values after an undetectable or nadir value for surgically managed and radiation-managed patients, respectively. The first detectable or increasing value after nadir-defined PSA failure and time zero was defined as the day of surgery or the last day of radiation therapy. If the PSA level never became undetectable postoperatively, then PSA failure was defined to be at time equal to zero. Patients who were found to have positive pelvic lymph nodes at the time of frozen section or at final pathologic section were begun on androgen suppression therapy and therefore were considered treatment failures at time zero. The probability of 2-year PSA failure was calculated from the coefficients of the Cox model. The 95% confidence intervals for the 2-year PSA failure probabilities were calculated using a bootstrapping procedure with 2,000 replications. The marginal proportion of variation explained (mPVE) in the posttherapy PSA data was calculated for each of the clinical predictors in both the RP and RT data sets.

RESULTS

Time to PSA Failure Analyses

Table 2 lists the P values from the Cox regression multivariable analysis confirming the independent prognostic significance (P < .0001) of the pretreatment PSA, biopsy Gleason score, and AJCC clinical stage to predict time to
posttreatment PSA failure. The values of the mPVE in the time to postoperative and postradiation PSA data are also listed in Table 2. These values for the PSA, biopsy Gleason score, and AJCC clinical stage were 20%, 6%, and 9% for the preoperative group and 16%, 7%, and 2% for the preradiation group. These results suggest that other parameters are still needed to account for the remainder of the variation in the posttherapy PSA data.

**PSA Failure Stratified by PSA, Biopsy Gleason Score, and AJCC Clinical Stage**

Tables 3A and 3B are a compilation of the 2-year PSA failure rates and the respective 95% confidence intervals stratified by preoperative PSA group (≤ 4, > 4 to 10, > 10 to 20, > 20 ng/mL), biopsy Gleason score (2 to 4, 5 to 6, 7, 8 to 10), and AJCC clinical stage for RP- and RT-managed patients, respectively. Two-year PSA failure rates ranged from 4% to 96% in RP-managed patients and from 5% to 80% in RT-managed patients. Patients with at least a 50% risk of PSA failure within 2 years, whether managed by RP or RT, included primarily those with biopsy Gleason scores of at least 8 or PSA levels of more than 20 to 50 ng/mL. However, the combination of factors such as PSA level more than 10 to 20 ng/mL, biopsy Gleason score 7, and AJCC clinical stage T2c also placed the patient at high risk for PSA failure.

**DISCUSSION**

In this study, nomograms were developed to predict 2-year PSA failure rates stratified by the pretherapy PSA level, biopsy Gleason score, and 1992 AJCC clinical stage for patients undergoing either RP or RT. Despite the independent statistical significance of all three clinical factors to predict time to posttherapy PSA failure (P < .0001), most of the variation in the posttherapy PSA data was not accounted for on the basis of the pretreatment PSA, biopsy Gleason score, and AJCC clinical stage. Specifically, upon examining the mPVE values, which describe the percentage of variation in the posttherapy PSA data explained by each of these three parameters, individual values ranged from 6% to 20% and 2% to 16% for the RP and RT data, respectively. These results suggest that a significant amount of the variation in the postoperative and postradiation PSA data needs to be explained by other clinical, pathologic, and/or molecular factors that have not yet been analyzed or determined. Numerous candidates for advances in this area include diagnostic imaging modalities (eg, color Doppler, 23

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**Table 2. P Values and mPVE Results from Cox Regression Multivariable Analysis for the Surgically Managed Patients at PEN and Radiation-Managed Patients at JCRT**

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<th>JCRT (n = 762)</th>
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<tr>
<td></td>
<td>P</td>
<td>mPVE (%)</td>
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<tr>
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<td>Biopsy Gleason score</td>
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**Table 3. Percent PSA Failure at 2 Years (and 95% Confidence Intervals), Stratified by Pretreatment PSA, AJCC Clinical Stage, and Biopsy Gleason Score**

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<th>Pretreatment PSA (ng/mL)</th>
<th>Biopsy Gleason Score</th>
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<td>B. Radiation-Managed Patients at JCRT (n = 762)</td>
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and colleagues,30 who have shown that the ability of patients. This finding was further supported by Cadeddu
distant failure as a site of first failure in the majority (65%)
colleagues,16 early postoperative PSA failure translated into
score of at least 8. The association between early PSA failure
and subsequent distant failure has previously been sug-
predicting volume of prostate cancer11). Further investigation
in PSA outcome prediction is still needed and is
currently under way.
The main goal of this study was to be able to identify
patients who were the most likely to harbor occult micrometa-
static disease at the time of definitive local therapy by
identifying patients whose probability of PSA failure within
2 years after treatment was at least 50%. These patients were
predominantly, but not exclusively, those who had a pretreat-
ment PSA level in excess of 20 ng/mL or a biopsy Gleason
score of at least 8. The association between early PSA failure
and subsequent distant failure has previously been sug-
suggested. Specifically, in a previous study by Partin and
colleagues,16 early postoperative PSA failure translated into
distant failure as a site of first failure in the majority (65%)
of patients. This finding was further supported by Cadeddu
and colleagues,30 who have shown that the ability of
postprostatectomy external-beam RT to cause an increasing
PSA postoperatively to become undetectable decreased
dramatically as the interval to postoperative PSA failure
shortened. In particular, only 6% of patients receiving
postprostatectomy RT responded if PSA failure occurred
within the first postoperative year, supporting the existence
of micrometastatic disease outside of the surgical bed in the
majority of patients who experienced early postoperative
PSA failure. Lee and colleagues31 have shown that in a
cohort of RT-managed patients, the estimated 5-year rate of
distant metastases was 75% in men whose PSA failure
occurred within the first year after the completion of RT.
Therefore, data from both surgically managed and radiation-
managed patients support the association between early PSA
failure and subsequent distant failure.

Given these results and the information in this report, an
argument can be made to select patients at high risk for early
postoperative or postradiation PSA failure for trials of
adjuvant systemic and improved local therapies. Currently,
for men with localized disease, the use of RT with or without
androgen suppression is being studied by the Radiation
Therapy Oncology Group (RTOG 9408, 9413). However,
considering the magnitude of the distant failure rate (65% to
75%) experienced by men with early PSA failure after RP or
RT, and the inability of postprostatectomy RT alone to make
a significant impact on subsequent PSA control in patients
with early postoperative PSA failure, attempts beyond
androgen suppression may be necessary to improve outcome
significantly. Perhaps, improvements may be realized by
studies taking a multimodality (ie, chemohormonal) ap-
proach to adjuvant and/or neo-adjuvant systemic therapy in
these selected patients as well as continuing to make
attempts to improve local therapy (eg, three-dimensional
conformal RT dose escalation).

In conclusion, patients at high risk (> 50%) for early
(≤ 2 years) PSA failure could be identified on the basis of
the type of local therapy received and clinical information
obtained as part of the routine work-up for localized prostate cancer. The results of this study suggest
that these patients are primarily, but not exclusively, those
men with a pretreatment PSA level of more than 20 ng/mL or
a biopsy Gleason score of at least 8. Although a further
search for improved parameters of PSA outcome prediction
is still needed, selection of these men for trials evaluating
adjuvant systemic and improved local therapies may be
justified.

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