

A Model to Optimize Followup Care and Reduce Hospital Readmissions after Radical Cystectomy

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Abbreviations and Acronyms

SID = State Inpatient Database

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Purpose: Radical cystectomy has one of the highest readmission rates across all surgical procedures at approximately 25%. We developed a mathematical model to optimize outpatient followup regimens for radical cystectomy.

Materials and Methods: We used delay-time analysis, a systems engineering approach, to maximize the probability of detecting patients susceptible to readmission through office visits and telephone calls. Our data source includes patients readmitted after radical cystectomy from the Healthcare Cost and Utilization Project State Inpatient Databases in 2009 and 2010 as well as from our institutional bladder cancer database from 2007 to 2011. We measured the interval from hospital discharge to the point when a patient first exhibits concerning symptoms. Our primary end point is 30-day hospital readmission. Our model optimized the timing and sequence of followup care after radical cystectomy.

Results: The timing of office visits and telephone calls is more important in detecting a patient at risk for readmission than the sequence of these encounters. Patients are most likely to exhibit concerning symptoms between 4 and 5 days after discharge home. An optimally scheduled office visit can detect up to 16% of potential readmissions, which can be increased to 36% with 1 office visit followed by 4 telephone calls.

Conclusions: Our model improves the detection of concerning symptoms after radical cystectomy by optimizing the timing and number of outpatient encounters. By understanding how to design better outpatient followup care for patients treated with radical cystectomy we can help reduce the readmission burden for this population.

Key Words: patient readmission, cystectomy, postoperative care, ambulatory care

EARLY rehospitalization is under intense scrutiny from clinician leaders and policymakers due their high cost, incidence and preventability.¹⁻⁴

Section 3025 of the Patient Protection and Affordable Care Act identified 30-day hospital readmissions as an important metric in measuring

quality of patient care. Under this section excessive hospital readmissions can be penalized with decreased reimbursements.^{4,5} Policymakers will be extending the application of this law to surgical procedures in the near future.^{5,6}

With a readmission rate approaching 25%, radical cystectomy for patients with bladder cancer may be a natural target if this policy is extended to surgical procedures.^{7,8} Despite multiple studies detailing the postoperative morbidity of radical cystectomy, the readmission rates for this procedure have remained stable over a decade.^{7,8} Certain aspects of followup care, including physician office visits and laboratory tests, have been associated with improved survival in patients undergoing radical cystectomy.⁹ However, the patterns of followup care associated with readmissions have not been widely studied. Innovative models of optimal outpatient followup after cystectomy discharge may help reduce readmission rates. Ideally, models would be able to predict when a patient is at greatest risk for readmission, thereby informing the optimal outpatient followup regimens. To aid in this process the input of systems engineers may be helpful since they examine time to failure dilemmas across a spectrum of industries. Leveraging their expertise may provide a novel way to reduce readmissions after cystectomy using robust, real-world modeling techniques.

In this study we developed a mathematical model to obtain the optimal post-discharge followup regimen to reduce readmissions after radical cystectomy. Our model examines how 2 common types of postoperative patient encounters (ie office visits and telephone calls) affect readmission rates.

METHODS

Data Source and Study Population

We used the Healthcare Cost and Utilization Project State Inpatient Databases for Florida, Iowa, New York, North Carolina and Washington to identify adults (18 years or older) who underwent radical cystectomy for bladder cancer in 2009 and 2010. Our model incorporated all patients who underwent radical cystectomy and were readmitted to the hospital.

To parameterize our model we required additional intervals for events occurring after discharge from the index hospitalization. Specifically we needed to know the distribution of time from initial hospital discharge to the time when a patient first experiences symptoms potentially causing a readmission. These symptoms include fever, nausea, emesis and postoperative pain, which are not easily discernible in national longitudinal hospital care databases. Therefore, we conducted a retrospective medical record review of radical cystectomy performed at our institution between 2007 and 2012. Two data extractors (NK and BL) independently collected the data to ensure fidelity of the results. We then determined the

distribution of the time from index hospital discharge to the onset of symptoms before readmission. The interval from when a patient first exhibits symptoms that precede a readmission to the time of readmission is defined as the delay time.

Delay-Time Model Formulation

We developed an optimization model of outpatient followup practices after radical cystectomy to examine the varying effect of office visits and telephone calls on detecting patients at risk for readmission. Our model is based on a systems engineering methodology known as delay-time analysis. Given the desired number of patient encounters, we determined the optimal followup regimen, which included timing and sequence of office visits and telephone calls.¹⁰ The primary end point of our study is 30-day hospital readmission after radical cystectomy.

Within the framework of delay-time analysis the patient represents the system, any concerning symptoms that develop after discharge indicate defects in the system and readmissions represent failures of the system. We assume that time, denoted as t , has a maximum value of 30 days (based on the current Centers for Medicare and Medicaid Services definition for hospital readmission).⁵ As shown in figure 1, a patient discharged home at time t_1 is assumed to be in stable condition. The patient could then become symptomatic at time t_3 but a patient encounter at time t_2 would be considered ineffective (because the patient has not yet experienced any indications that warrant readmission). In contrast, a patient encounter at time t_3 and beyond could potentially identify the symptoms that led to readmission. If the patient is readmitted at time t_5 , the delay-time is defined as the time elapsed from t_3 to t_5 . We examined the differences in the 2 most common patient encounter practices (ie office visits and telephone calls) used to detect those patients at risk for readmission.

Statistical Analysis

Using this framework we determined the optimal post-discharge monitoring regimens that maximized the clinical detection probability, which is the likelihood of identifying a patient becoming symptomatic after initial hospital discharge. We assumed an office visit is 40% more accurate in detecting symptoms in at risk patients than telephone calls, although we were able to vary this in our model. Sensitivity analysis was performed regarding the detection probability of telephone calls. In our baseline model (which assumes a 60% detection probability for telephone calls) 1 office visit was found to be equivalent to 2.57 telephone calls (see supplementary Appendix,

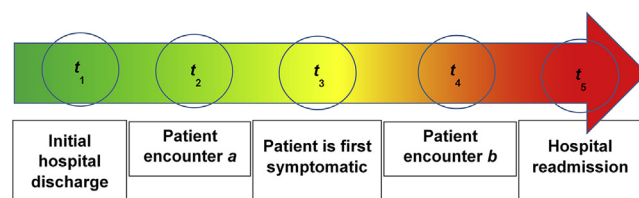


Figure 1. Theoretical basis for delay-time readmission model

<http://jurology.com/>). We tested different combinations of office visit and telephone call sensitivities. We varied the sensitivity of office visits and telephone calls among 20%, 40%, 60%, 80% and 100%. Our results were robust as long as the sensitivity of a telephone call was greater than 20% (see supplementary Appendix, <http://jurology.com/>).

Additional telephone calls are necessary to equal 1 office visit as the detection probability of telephone calls decreases. For instance, if a telephone call has a detection probability of 40%, 1 office visit would be equivalent to 3.3 telephone calls. If the detection probability of telephone calls further decreased to 20%, 6 telephone calls would be equivalent to 1 office visit. To validate our findings we applied the optimal post-discharge monitoring policy obtained from the 2010 SID patient cohort to the 2009 SID cohort. All computational analyses were performed using the Flux High Performance Computing cluster provided by the Advanced Research Computing Technology Services at the University of Michigan, Ann Arbor. The University of Michigan institutional review board approved the study protocol.

RESULTS

Our study population included patients discharged from the hospital after undergoing radical cystectomy in 2010 in the SID (717, mean age of 68 years) as well as patients with bladder cancer from our institutional database who underwent radical cystectomy from 2007 to 2011. The SID included 129 females and 588 males. In our institutional cystectomy database there were 79 females and 248 males (mean age 66 years) (table 1).

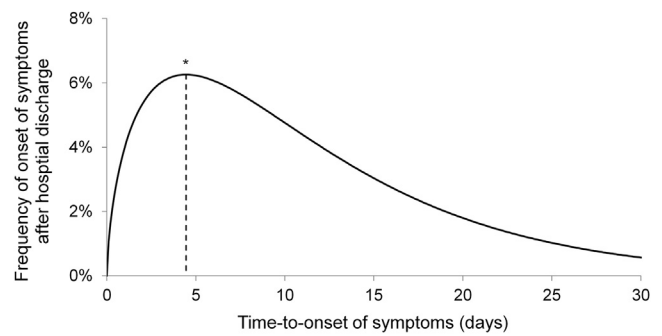
We first assessed the optimal timing of patient encounters after discharge home for patients who underwent cystectomy. As shown in figure 2, patients were most likely to experience symptoms that put them at risk for readmission between 4 and 5 days after initial discharge home. We found the maximal associated detection probability when a patient encounter occurred around this time (figs. 1 and 2).

Table 1. Demographic data of study population

	SID	Institutional Database
Mean age (SD)	68 (11)	66 (11)
No. female (%)	129 (18)	79 (24)
No. race (%):*		
White	532 (74)	313 (97)
Nonwhite	117 (15)	11 (3)
No. American Society of Anesthesiologists® (ASA®) classification (%):†		
I or II	—	145 (44)
III or Greater	—	182 (56)
No. Charlson comorbidity index score (%):‡		
3 or Less	611 (78)	—
Greater than 3	168 (22)	—

* Data on race partially missing in SID.

† ASA classification not captured in SID and Charlson comorbidity index not captured in institutional bladder cancer database.



* Most common time to onset of symptoms is between 4 and 5 days after initial hospital discharge

Figure 2. Time to onset of symptoms warranting rehospitalization after radical cystectomy

We next compared a common 2-patient encounter post-discharge monitoring regimen with optimal regimens obtained from our optimization model (table 2). A common outpatient followup policy involves calling the patient at 1 day after discharge followed by an office visit at 14 days, resulting in a detection probability of 12%. Our model shows the optimal 2-patient encounter monitoring regimen uses an office visit at day 4 and a telephone call at day 8 after discharge home. This results in the maximum clinical detection probability of 23% for a 2-patient encounter regimen.

In addition, we examined the effect of quantity of patient encounters. Increasing the number of patient encounters and increasing the number of office visits improves the detection probability. With 5 or fewer patient encounters, 1 office visit may be replaced with 2.6 telephone calls. An additional telephone call increases the detection probability by an average of 3.4% while replacing an existing telephone call with an office visit increases the probability by a similar margin (3.5%). As shown in table 3, the detection probability in a followup regimen of 4 encounters (consisting of 1 office visit and 3 telephone calls) is 32% and substituting a telephone call with an office visit increases the detection probability to 36%. However, a followup

Table 2. Sequence and timing of 2-patient encounter followup regimen and probability of identifying patients at symptom onset after radical cystectomy

Sequence of Pt Encounters*	Detection Probability (%)	2009 SID Detection Probability (%)
P ₁ , O ₁₄	12	13
P ₁ , O ₆	19	21
P ₆ , O ₉	20	20
O ₇ , P ₁₁	21	20
O ₆ , P ₁₃	21	21
O ₄ , P ₈	23	24

* O_n, office visit on the nth day after discharge home. P_n, telephone call on the nth day after discharge.

Table 3. Varying number of patient encounter followup regimens and probability of identifying patients at symptom onset after radical cystectomy

Sequence of Pt Encounters*	Detection Probability (%)	2009 SID Detection Probability (%)
O ₇	16	15
O ₆ , P ₁₀	23	21
O ₅ , P ₉ , P ₁₂	28	27
O ₅ , P ₈ , P ₁₀ , P ₁₃	32	31
O ₄ , O ₈ , P ₁₁ , P ₁₄	36	35
O ₄ , P ₇ , P ₉ , P ₁₁ , P ₁₄	36	35

* O_n, office visit on day n. P_n, telephone call on day n.

regimen of 5 patient encounters, consisting of an office visit followed by 4 telephone calls, would also achieve a detection probability of 36%.

We also determined the effect of order or sequence of patient encounters on detection probability. We calculated the optimal detection probabilities for all possible combinations of 2 to 10-patient encounter followup regimens with up to 3 office visits. We then compared, among all possible combinations, the regimen with the lowest detection probability vs the regimen with the highest detection probability. The difference in detection probability between any 2 regimens ranges from 0.2% to 0.4% with an average difference of 0.3%, which indicates that the timing of patient encounters has a much greater effect on the detection probability than the actual sequence of the patient encounters. Hu et al provide further detail and additional analyses.¹⁰

To adjust for preoperative differences in medical comorbidity we performed a sensitivity analysis stratified by the Charlson comorbidity index of all patients with scores of 3 or less vs scores greater than 3 (results not shown). We developed a unique model for each new subset of the study population (in this case, Charlson comorbidity index) to compare the maximum detection probability between the groups. There was no significant difference in the detection probability between patients treated with cystectomy with Charlson comorbidity scores of 3 or less vs those with scores greater than 3. To further test our findings we obtained the optimal regimen based on 2010 SID cystectomy cases and then used the 2009 SID population as the validation cohort (tables 2 and 3). The clinical detection probabilities in the validation cohort were similar to those of the original cohort, indicating the models are robust when applied to a novel patient cohort.

DISCUSSION

Rehospitalization after radical cystectomy remains a significant burden for patients and providers. The cost of rehospitalization for Medicare beneficiaries increased from \$17 billion in 2004 to more than \$41

billion per year in 2011.^{4,11} To our knowledge no literature exists regarding the optimum outpatient followup policy for patients undergoing radical cystectomy. Individual telephone counseling has already been shown to be an effective strategy for oncologic care with respect to symptom management and the treatment of side effects.¹²⁻¹⁴ Our mathematical model attempts to address this knowledge gap by using delay-time analysis. Similar mathematical modeling has been used in the finance, automotive and airline industries and to a limited extent in medicine.¹⁵⁻¹⁸

The findings from this study indicate that the detection probability can be improved simply by changing the timing of encounters even in an institution that uses a 2-patient encounter followup policy. The chance of detecting patients who underwent cystectomy at risk for readmission is greatest around 4 to 5 days after discharge home. Thus, an office visit scheduled at or after 4 to 5 days has a greater chance of detecting patients potentially at risk for readmission vs a patient encounter scheduled before or after this time.

In terms of quantity vs quality of followup care, an additional telephone call vs substitution of an existing telephone call with an office visit have similar benefits. This finding has significant implications because patients often travel long distances for oncologic surgical care. Moreover patients who travel longer distances to seek complex cancer care also have higher rates of readmission and, subsequently, higher emergency department resource use compared to those who had surgery closer to home.¹⁹ This has salient implications to patients undergoing radical cystectomy since this procedure has become increasingly regionalized in the last decade to select medical centers, which only further constrains vulnerable patients.²⁰ Increased adoption of followup telephone calls for postsurgical patients is less resource intensive for hospitals and can reduce an unnecessary travel burden for patients, especially for those who may live in underserved areas.

In addition to showing the benefits of increased outpatient encounters, our model suggests that the specific order of followup encounters is less important than the timing of care. In designing an outpatient care policy for patients treated with cystectomy, the timing of patient encounters appears to be a key factor in detecting potential readmissions.

Our findings have real-world implications. Our model offers a concrete testable followup policy for radical cystectomy cases that other institutions could compare with their current approach. Furthermore, we can apply our model to almost any surgical procedure such as liver transplantation or

esophagectomy, which both have readmission rates higher than 17%.²¹ All of these operations could serve as potential substrates for our model.

In attempting to model outpatient followup policy for patients treated with cystectomy we rely on several assumptions. It is difficult to quantify the exact accuracy of an office visit vs a telephone call. However, we are confident that an office visit should be significantly more accurate than a telephone call. In addition, our model treats each patient as a separate but identical system. We were able to perform a sensitivity analysis that resulted in 2 separate models for patients treated with cystectomy with Charlson comorbidity scores of 3 or less vs scores greater than 3. The resulting optimal detection probabilities for timing and sequence had no appreciable difference between the 2 models (results not shown). This finding suggests that the time to readmission and, consequently, the optimal timing of patient encounters is similar between the 2 groups. Helm et al describe other methods for generating individual time to readmission risk curves.²² Furthermore, our model produced similar detection probabilities when validated against the 2009 SID cystectomy cohort in out-of-sample testing.

Another limitation is that our model focuses solely on hospital readmissions. In our theoretical model a clinical encounter before a patient begins to feel ill is not an effective use of resources. However, a patient encounter at this time may actually prevent a readmission through patient education. For

instance, patients could be instructed to walk more frequently or increase their oral intake. Our model does not account for the diversity in outpatient followup care practices. Certain institutions use visiting nurses, enhanced recovery pathways, scheduled intravenous fluid therapy, fast track programs and other strategies to optimize outpatient followup care after radical cystectomy.^{23,24} Although we do not account for all of these practice patterns, office visits and telephone calls are still the most commonly used followup care methods. Finally, we did not include any consideration of costs in this model. Given that bladder cancer has the highest cost per patient from diagnosis to death compared to all cancer sites, further research should consider the cost implications of various outpatient followup regimens.²⁵

CONCLUSIONS

The timing of outpatient followup care is one of the key determinants in identifying cystectomy cases at the onset of symptoms after initial hospital discharge. Moreover increasing the number of telephone calls can serve as an excellent proxy for an additional office visit with respect to the clinical detection probability. Finally, the order of patient encounters does not appear to carry as much weight as the specific timing of followup care. Continued efforts to understand the best followup strategies for radical cystectomy cases in the pre-admission interval may help to reduce the readmission burden.

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EDITORIAL COMMENT

In this study Krishnan et al adopt the engineering principle of time-delay analysis to construct a mathematical model for standardized outpatient care in the perioperative period following radical cystectomy. In the era of accountable care organizations, standardization of care to reduce hospital admissions is increasingly crucial to surgical practice, and the authors are to be commended for their application of industrial analysis to address this important problem.

Additional studies are required to validate this model in a prospective fashion, determine potential cost savings and identify ancillary interventions

such as laboratory evaluations that may be critical in preventing readmission. Furthermore, with the continued evolution of urological practice through the use of physician extenders and video visits, there is a need to characterize the specific nature of each followup encounter beyond the distinction between call or visit and to incorporate these methods of care delivery in subsequent models.^{1,2}

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