Evaluation of the Risk Assessment and Prediction Tool for Postoperative Disposition Needs After Cervical Spine Surgery

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BACKGROUND: Bundled care payment models are becoming more prevalent in neurosurgery. Such systems place the cost of postsurgical facilities in the hands of the discharging health system. Opportunity exists to leverage prediction tools for discharge disposition by identifying patients who will not benefit from prolonged hospitalization and facilitating discharge to post-acute care facilities.

OBJECTIVE: To validate the use of the Risk Assessment and Predictive Tool (RAPT) along with other clinical variables to predict discharge disposition in a cervical spine surgery population.

METHODS: Patients undergoing cervical spine surgery at our institution from June 2016 to February 2017 and over 50 yr old had demographic, surgical, and RAPT variables collected. Multivariable regression analyzed each variable's ability to predict discharge disposition. Backward selection was used to create a binomial model to predict discharge disposition.

RESULTS: A total of 263 patients were included in the study. Lower RAPT score, RAPT walk subcomponent, older age, and a posterior approach predicted discharge to a post-acute care facility compared to home. Lower RAPT also predicted an increased risk of readmission. RAPT score combined with age increased the predictive capability of discharge disposition to home vs skilled nursing facility or acute rehabilitation compared to RAPT alone ($P < .001$).

CONCLUSION: RAPT score combined with age is a useful tool in the cervical spine surgery population to predict postdischarge needs. This tool may be used to start early discharge planning in patients who are predicted to require post-acute care facilities. Such strategies may reduce postoperative utilization of inpatient resources.

KEY WORDS: Discharge disposition, Predictive scale, Spine

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Value-based care, as determined by patient reported outcomes and costs, is becoming increasingly important to both research and clinical reimbursement.[1,2] Historically, surgeons have made efforts to reduce length of stay (LOS) as a cost-saving measure. However, this may have led to increased discharge rates to expensive post-acute care facilities such as acute rehabilitation (AR) and skilled nursing facilities (SNF).[3] Recently, bundled care payments have been explored as a mechanism to align physician incentives with healthcare value.[4] Costs of post-acute care services make up a significant proportion of these bundled payments.[5] Although some patients will need to be discharged to SNF or AR, selective increases in LOS may reduce the need for these resources in other patients, and thus decrease the total care cost. SNF or AR may be the inevitable destination for other patients, and facilitating early discharge may decrease inpatient resource utilization. Accurate selection of these patients requires clinical decision tools that can identify the patients that would benefit from expedited discharge or a longer LOS.

ABBREVIATIONS: AR, acute rehabilitation; **ASA,** The American Society of Anesthesiologist; **CI,** confidence interval; **CPT,** Current Procedural Terminology; **ER,** Emergency Room; **IRB,** Institutional Review Board; **LOS,** length of stay; **NQII,** Neurosurgery Quality Improvement Initiative; **OR,** odds ratio; **RAPT,** Risk Assessment and Predictive Tool; **SNF,** skilled nursing facility

The Risk Assessment and Predictor Tool (RAPT) was developed to assess the need for postsurgical inpatient care within orthopedic surgery populations.[6-10] RAPT evaluates 6 domains including age, gender, distance able to walk, gait aids, community support, and home support. Although recently validated in a heterogeneous neurosurgical population, it has not been exclusively applied to patients undergoing elective cervical surgery.[11] Clear differences likely exist between cervical spine surgery patients and other orthopedic and neurosurgical patients, but the domains assessed preoperatively in RAPT may still be pertinent to these patients. The objective of this study was to validate the RAPT score, as well as other preoperative patient characteristics, for predicting post-acute care needs in cervical neurosurgery populations.

METHODS

Patient Selection

This study was approved by the Institutional Review Board (IRB) at the Hospital of the University of Pennsylvania. IRB number for this study is 826300. In this study, patients over the age of 18 and undergoing elective cervical spine surgical intervention across our health system between June 2016 and February 2017 were enrolled prospectively and retrospectively for RAPT subcomponent data collection prior to surgical intervention and retrospective analysis was performed (n = 278). A waiver of informed consent was granted by the University of Pennsylvania IRB, as this study was considered to be minimal risk to patients. All ethical guidelines and rules were followed to protect patient privacy. The health system is composed of 1659 total beds spanning 3 sites. Elective procedures were defined as those that had preoperative outpatient visits in which RAPT data could be prospectively collected prior to a defined surgery date. Patient demographic information and RAPT scores were recorded at the preoperative office visit using the Neurosurgery Quality Improvement Initiative (NQII) EpiLog program, a nonproprietary clinical research tool that interfaces with the electronic health record. RAPT score components are shown in Table 1.[9] Variables collected by the NQII EpiLog tool included age, comorbidities, body mass index, The American Society of Anesthesiologist Physical Status Classification System (ASA grade), and RAPT score. Comorbidities collected included hypertension, diabetes mellitus, cancer, chronic obstructive pulmonary disease, congestive heart failure, coronary artery disease, and chronic renal failure. LOS, the hospital where the procedure was performed, and levels of surgery were also collected. Anterior vs posterior approach was determined based on Current Procedural Terminology (CPT) code.

Patient surgical information and discharge destination were collected by the EpiLog tool and categorized into home discharge, AR, or SNF. Patients were excluded if they expired during their hospital stay or did not have a discharge location that fit into these broad categories (n = 15). For analysis that only included RAPT components, patients were excluded if they were under the age of 50 because the RAPT score has not been validated in this population (n = 59). A small cohort of consecutive patients (n = 91) had EQ5D scales prospectively captured pre- and postprocedure and underwent cost analysis of intraoperative supply costs.

Statistical Analysis

Two models were used for analysis of factors related to discharge disposition. Model A used home, AR, and SNF as discrete categories of postacute disposition. Model B combined AR and SNF so that there were only 2 options for discharge: home or AR/SNF, and allowed the prediction of inpatient postacute care resources, regardless of discharge disposition. Univariate analysis was used to determine which variables were associated with discharge disposition. Both models were further analyzed using logistic regression. Age and body mass index were included as continuous variables, whereas RAPT score, RAPT subcomponent, and ASA grade were included as ordinal variables. All other variables were categorical. A binomial model to predict discharge disposition defined by model B was created using backward selection and variables significant on univariate analysis. This model excluded LOS, as this would not be known preoperatively. *P*-values of .05 were used to define statistical significance. All analyses were performed using SPSS (IBM Analytics, Armonk, New York), R Statistics (R Core Team, Vienna, Austria, 2017), and SAS Version 9.4 (SAS Institute Inc., Cary, North Carolina).

RESULTS

RAPT Score Prediction of Discharge Disposition

A total of 263 patients remained in the study after exclusions. Mean RAPT scores by model and disposition are shown in Table 2. Using model A, RAPT scores effectively predicted discharge disposition ($P = .003$). Higher RAPT scores predicted discharge home as compared to AR (odds ratio [OR] 1.4; 95% confidence interval [95% CI] 1.2-2.1) or SNF (OR 1.5; 95% CI 1.1-1.9) (Figure 1). However, there was no significant difference in RAPT scores between patients discharged to SNF and AR. Using model B, RAPT score also predicted discharge disposition ($P < .001$), with higher scores being associated with home discharge. In addition, every unit increase in RAPT score increased the chance of disposition to home by 46.9% (OR 1.5; 95% CI 1.2-1.8).

Individual RAPT Components Predict Discharge Disposition

RAPT subcomponents included walk, gait, and home support. The percent of patients discharged to each location by RAPT walk score is shown in Figure 2. Both model A and model B demonstrated only the RAPT walk score to be predictive of home discharge (model A, $P = .034$ for AR and $P = .002$ for SNF; model B, $P = .002$) in both models. Both models found that every unit increase in RAPT walk score led to an increase in chances of being discharged home as opposed to SNF or AR (model A, OR 3.4; 95% CI 1.5-7.6 for AR, OR 3.8; 95% CI 1.6-8.9 for SNF; model B, OR 3.7; 95% CI 1.6-8.4).

Preoperative Patient Characteristics Influence on Postoperative Postacute Care Needs

Demographics for the cohort are shown in Table 3. Males were less likely to be discharged to home in model A compared to AR

TABLE 1. RAPT Score Subcomponents[9]

Points	0	1	2	3
Age	>75	66-75	50-65	–
Sex	–	Female	Male	–
Walk	Housebound	1-2 blocks	2 or more blocks	–
Gait assist	Crutches/frame	Single-point assist	None	–
Community support	2 or more per week	None/1 per week	–	–
Home support	Will live alone	–	–	Will live with someone postoperatively

RAPT, Risk Assessment and Predictive Tool.

TABLE 2. Mean RAPT Scores by Model and Discharge Disposition, excluding Patients With Age < 50 (n = 59)

	Model A			Model B		
	Home	AR	SNF	Home	AR//SNF	*p*
N	188 (90%)	7 (3%)	15 (7%)	188 (90%)	22 (10%)	–
Mean (SD)	10.0 (1.8)	8.6 (1.5)	8.5 (1.9)	10.0 (1.8)	8.5 (1.7)	<.001

AR, acute rehabilitation; RAPT, Risk Assessment and Predictive Tool; SNF, skilled nursing facility.

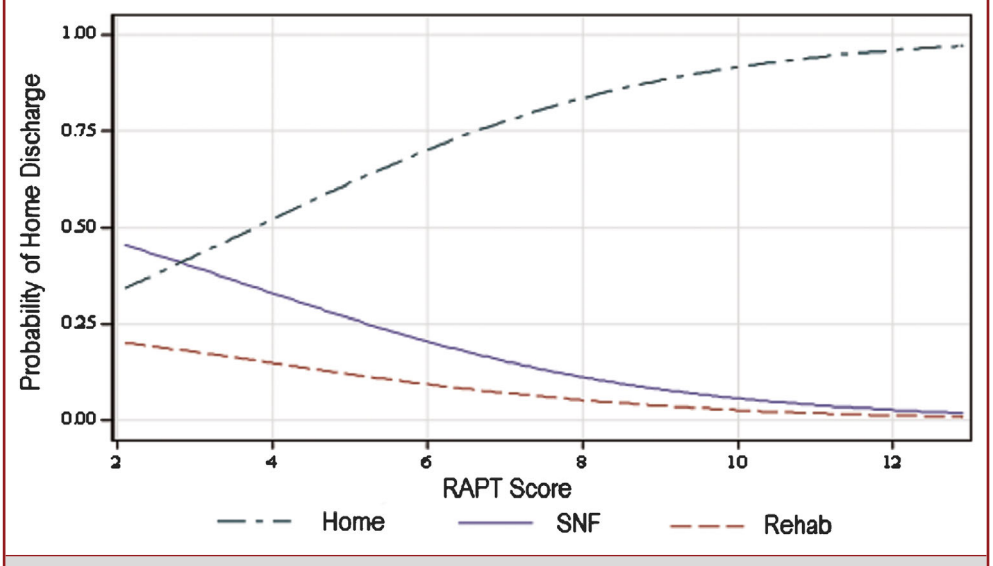

FIGURE 1. *RAPT score's prediction of discharge disposition for model A.*

(OR 0.3; 95% CI 0.1-0.9; $P = .039$) or SNF (OR 0.3, 95% CI 0.1-0.9; $P = .039$). In model B, males were less likely to be discharged home compared to AR or SNF (OR 0.4; 95% CI 0.2-0.9; $P = .044$). Both models demonstrated that age was a significant predictor of discharge disposition (Figure 3). Older patients had an increased chance of being discharged to AR or SNF compared to home Figure 3. Model B demonstrated that every year of age reduced the chance of being discharged home by 8.8% (OR 0.9; 95% CI 0.9-1.0). Table 4 demonstrates the association of each factor with home discharge compared to AR or SNF in model A and AR/SNF in model B.

When individually analyzing comorbidities, model A did not demonstrate significant association with predicting discharge disposition. However, in model B, hypertension

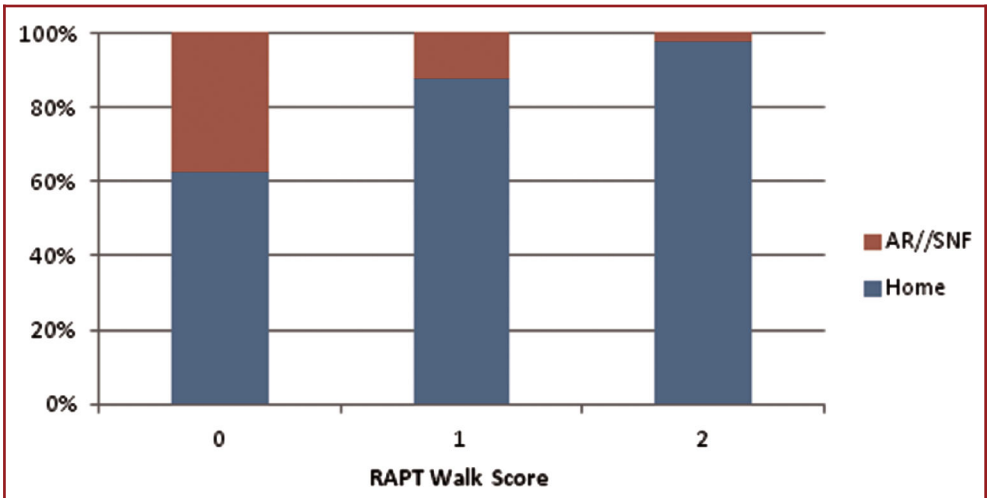

FIGURE 2. *Discharge disposition stratified by RAPT walk score.*

TABLE 3. Patient Demographics of the Analytic Cohort

Variable name	Overall (n = 263)
Age, mean (SD)	57.9 (10.8)
Female sex	129 (49%)
ASA grade, mean (SD)	2.5 (0.5)
BMI, mean (SD)	29.0 (5.5)
Smoking status, yes	53 (20%)
Approach	
Anterior	137 (54%)
Posterior	56 (22%)
Anterior and posterior	59 (23%)
Length of stay (hours), mean (SD)	100 (151.1)
Disposition	
Home	241 (92%)
Acute rehabilitation	7 (3%)
Skilled nursing facility	15 (6%)
ER visit within 30 d	11 (4%)
Admission within 30 d	34 (13%)
Office visit within 30 d	83 (32%)

ASA, The American Society of Anesthesiologist; BMI, body mass index.

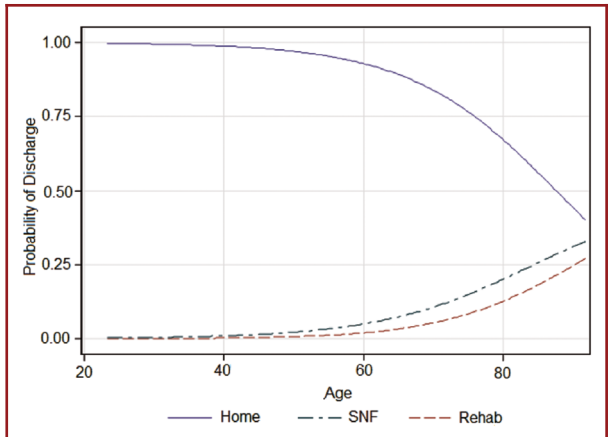

FIGURE 3. *Discharge disposition as predicted by age in model A.*

predicted facility disposition (OR 2.9; 95% CI 1.0-8.4; $P = .036$).

Peri- and Postoperative Factors Influence Discharge Disposition

Hospital LOS was predictive of disposition to SNF in model A and AR or SNF in model B in ($P < .001$ and $P < .001$ respectively). Patients that had an increased LOS had a decreased chance of being discharged to home. Additionally, model B showed that each additional hour spent in the hospital decreased the chance of being discharged home by 0.5% (OR 1.0; 95% CI 1.0-1.0). Month and season of surgery did not predict increased postacute needs.

Although specific surgeon did not predict disposition in either model, location of the surgery was significant in both. With model A, patients undergoing surgery at the hospital 1 compared to hospital 2 were significantly more likely to be discharged home than to SNF or AR (OR 3.5; 95% CI 1.4-8.6; $P = .007$).

Using model A, increasing the number of levels that are surgically treated decreased the likelihood of home disposition compared to SNF (OR 0.8; 95% CI 0.5-1.0; $P = .019$). This relationship was not significant for home vs AR. In model B, each additional surgically treated level decreased the change of home discharge (OR 0.8; 95% CI 0.6-1.0, $P = .040$).

TABLE 4. Odds Ratio (OR) for Home Discharge Compared to AR or SNF in Model A and Model B

Variable name	Model A				Model B	
	Home vs AR		Home vs SNF		Home vs AR or SNF	
	OR (95% CI)	*P*	OR, (95% CI)	*P*	OR (95% CI)	*P*
RAPT score	1.4 (1.2-2.1)	.003	1.5 (1.1-1.9)	.003	1.5 (1.2-1.8)	<.001
RAPT subcomponents						
Age	0.9 (0.8-1.0)	.014	0.9 (0.9-1.0)	.004	0.9 (0.9-1.0)	<.001
Sex (male)	0.3 (0.1-0.9)	.039	0.3 (0.1-0.9)	.039	0.4 (0.2-0.9)	.044
Distance able to walk	3.4 (1.5-7.6)	.034	3.8 (1.6-8.9)	.002	3.7 (1.6-8.4)	.002
Gait aids	1.3 (0.6-2.9)	.475	1.4 (0.6-3.0)	.413	1.3 (0.6-2.9)	.464
Home support	6.1 (0.4-8.7)	.186	2.0 (0.1-4.7)	.236	5.8 (0.4-8.4)	.198
BMI	1.0 (0.8-1.1)	.861	1.1 (0.9-1.2)	.119	1.1 (0.9-1.2)	.171
Smoking status, yes	1.5 (0.5-4.1)	.388	1.5 (0.6-4.2)	.388	0.6 (0.2-1.7)	.406
Length of stay (hours)	1.0 (1.0-1.0)	.182	1.0 (1.0-1.0)	<.001	1.0 (1.0-1.0)	<.001
Levels surgically treated	1.0 (0.5-2.2)	.950	0.8 (0.5-1.0)	.019	0.8 (0.6-1.0)	.040

AR, acute rehabilitation; BMI, body mass index; CI, confidence interval; RAPT, Risk Assessment and Predictive Tool; SNF, skilled nursing facility.

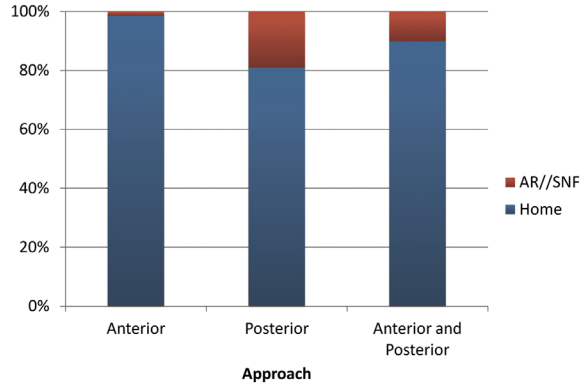

FIGURE 4. *Discharge disposition stratified by anterior and posterior surgical approach.*

Finally, although the number of CPT codes used for the surgery was not significant in predicting disposition for either model A or B, specific codes were predictive. Patients undergoing cervical anterior arthrodesis (CPT 22551) were significantly more likely to be discharged home than other procedure codes using both models A and B ($P < .001$ for both; model B, OR 37.3; 95% CI 12.4-50.5). Differences in anterior vs posterior approaches are shown in Figure 4.

RAPT Score Prediction of Quality-Adjusted Life Years Gained, Cost, and Readmission

In the subset of patients, RAPT score was not significantly predictive of quality-adjusted life years gained from surgery. However, it was predictive of surgical supply cost ($P = .013$) and each unit increase in RAPT score reduced the cost of surgery by $388. Taking each quartile of surgical cost, it was found that RAPT significantly predicted cost at the median and third quartile ($P = .011$ and $P < .001$, respectively). At the median cost, a unit increase in RAPT decreased surgical cost by $446, whereas at the third quartile, each increase in RAPT reduced cost by $922.

In the full cohort, RAPT score was able to significantly predict 30-d readmission (OR 0.7; 95% CI 0.6-0.9; $P = .001$), but not a visit to the Emergency Room (ER) within 30 d. Each unit increase in RAPT decreased the chance of 30-d readmission by 26.9%. In addition, outpatient visits were analyzed to see if they influenced readmission and ER visit rates. An office visit was not significantly associated with a decrease in either of these rates.

Enhancing Preoperative Disposition Prediction for Model B

Our binomial logistic regression model created with backward selection showed that only RAPT walk score and age provided increased predictive capability than when used individually. In the new model, each unit increase in RAPT walk led to a 325% increase in odds of discharge to AR or SNF (OR 4.245; 95% CI 2.159-8.347; $P < .001$). Each year increase in age decreased the odds of home discharge by 6% (OR 0.937; 95% CI 0.890-0.986; $P = .013$).

DISCUSSION

In this study, we demonstrated that RAPT score is an accurate tool to predict postacute care need in elective cervical spine surgery patients. In addition, we identified factors not captured by RAPT, such as age and number of levels operated on, that may be of use for predicting discharge disposition. Both higher RAPT and subcomponent RAPT walk scores increased the chance of discharge to home compared to inpatient facilities. Using this score, neurosurgeons may be able to reduce inefficiencies in discharge planning in order to facilitate early discharge to

postacute care facilities in patients that are not likely to benefit from prolonged hospitalization.

Although RAPT was designed for orthopedic surgery, our study demonstrates that it has predictive value in cervical neurosurgical populations.[6-10] In a previous paper, we validated the RAPT score in a heterogeneous neurosurgical population.[11] We noted that patients undergoing cervical surgery were more likely to be discharged home compared to lumbar and lumbosacral surgery. The current study expands our results to include predictors of postacute need in the cervical subgroup. Additionally, we included outcomes such as readmission, which are important to assess in the context of bundled payments. As we have validated RAPT within cervical spine surgery, future studies may determine a cutoff or include it in a nomogram to definitively predict the behavior of patients after spine surgery and precisely identify who will and will not require postacute care resources.

Alternative payment models have been proposed by the federal government in order to control healthcare spending.[13] The bundled care payment model is one such concept that reimburses a fixed amount for a set episode of care. The RAPT score may be used to drive these pathways, although further work must be done to identify both the clinical and economic impact of instituting RAPT. Early identification of patients that are likely to require AR or SNF could increase coordination between care teams and decrease unnecessary hospitalization while the patient awaits transfer. Alternatively, patients who are predicted to be discharged home might benefit from protocols aimed at early mobilization and physical therapy. Surgeons may prolong hospitalization in such patients in order to discharge them directly to home rather than a postacute care facility. As demonstrated in a recent decision analysis by Slover et al,[14] the cost of a longer hospital stay would likely offset the cost of utilization of AR of SNF in these patients.

The predictive capability of RAPT and the RAPT walk score in our models demonstrate that ambulation is a critical variable in the postoperative phase. Notably, patients that have poor baseline status are less likely to be able to fully participate in postoperative physical therapy and thus might require more services on discharge. This is supported by Shamaji et al,[15] who showed that patients with preoperative myelopathy have higher rates of postacute care utilization. Our study is the first to assess the predictive capability of preoperative ambulation on discharge disposition in cervical spine surgery. RAPT and RAPT walk might be used to stratify patients and preoperatively reserve beds at postacute care facilities to expedite postoperative transfer. Alternatively, for patients with relatively high RAPT scores, it may be used to determine if they can avoid discharge to a facility by marginally increasing their time in the hospital. Although implementation of risk scores similar to RAPT has demonstrated the ability to decrease discharge to facilities, it is unclear through which mechanism this occurs.[16]

Our predictors of facility discharge are similar to those found in the spinal surgery literature. Studies of several spinal surgeries have demonstrated that advanced age predicts facility discharge.[17-19] McGirt et al[20] developed a novel grading scale to predict extended LOS, readmission, or discharge to a facility after elective lumbar surgery. We found that an increase in the number of levels involved in the operation and a posterior approach led to increased likelihood of postdischarge resource utilization, similar to the result found by Murphy et al.[18] Larger surgeries involve more muscle dissection, larger incisions, and more postoperative pain. These patients are less likely to ambulate after surgery and less likely to participate in recovery protocols that increase the likelihood of home discharge. Our results are in line with Tanenbaum et al,[21] who, using a matched cohort, showed that patients undergoing posterior fusion have a 3-fold higher likelihood of discharge to facilities than anterior fusions. Because the approach is known preoperatively, these patients may benefit from discharge planning prior to surgery. We found that an increased LOS predicted discharge to a facility. This association has been noted across a variety of surgical subspecialties, including posterior spinal fusion.[17,22-25] Further studies might elucidate cost-effective measures, such as benchmark LOS, from which patients who are predicted to require postacute care facilities and are still in the hospital can be expedited to SNF or AR.

Importantly, our study indicates that patients who have preoperative decreased mobility have increased 30-d readmission rates. Lee et al[26] identified 6-min walking distance as a risk factor for complications. The literature has often focused on ambulation in the postoperative phase to predict discharge disposition. For example, step counts during the inpatient stay have been associated with readmission rates in multiple contexts.[27,28] Ambulation status should be recognized as an important predictor of postoperative need, regardless of the capacity to modulate it preoperatively. Physicians should work to both improve patient status preoperatively and employ it as a predictive tool. However, patients who are able to change their preoperative ambulation status may be different from those who are not, and this result is unlikely to be captured by the RAPT scoring system. Minnella et al[29] described a prehabilitation program that increased patients' walking status prior to surgery. They did not find a difference in readmission rates between patients with lower and higher baseline walking status after their participation in the program. However, their patient population was elderly and undergoing colorectal surgery. It remains to be determined if such a program is effective in patients with a neurogenic impairment.

The ability of our tool to predict readmission carries significant economic ramifications. Although rates of cervical spine surgery have decreased slightly in the last couple decades, the costs have significantly increased.[30,31] The rising cost across all surgeries has been attributed to inefficient care.[32] Discharging patients to continued care facilities requires a massive amount of planning and takes time to execute, which may prolong hospital LOS. As such, other high-risk specialties have developed successful preoperative prediction models for use in discharge planning.[33,34] In particular, bundled payments do not reimburse hospitals or

physicians for readmissions, so avoiding them is of great importance. By preoperatively identifying patients at high risk for readmission through RAPT scores, neurosurgeons may be able to provide them with increased home support or closer follow-up. The cost of providing more resources to these patients may be offset by the reduction in readmission risk. The readmission risk in patients with low RAPT scores also has implications for advocacy and payment reform. The case could be made to insurance companies to exclude patients at the highest risk of readmission from bundled-payment plans. However, there is a paucity of literature evaluating the economic impact of instituting RAPT as a clinical tool. More work must be done to determine if this tool, which is effective in its predictive capacity, can be leveraged to alter and improve course of care before widespread adoption.

Limitations

Our study is not without limitations. Patients were enrolled through a single neurosurgery department, which introduces selection bias. Our results may not be equally applicable to departments across the county, though our patients were drawn from multiple hospitals in a tertiary care system that serves a heterogeneous metropolitan community. Although our data are prospectively collected in these 263 patients, we have not yet prospectively evaluated the implementation of RAPT within our institution. Slover et al[12] evaluated the predictive capability of RAPT for patients undergoing spinal fusion at their institution; however, they did not evaluate whether discharge management was different before and after implementation. Additionally, there may be unmeasured variables such as socioeconomic and insurance status that were not included in our regression model, which may impact the decision to discharge a patent home or to a facility. Although we specifically examined cervical spine surgery, we did not account for preoperative diagnosis, which might affect discharge to home or a facility. Rare pathologies are likely underestimated within our cohort, and thus RAPT should be applied with caution to these patients. Although RAPT has been instituted at a variety of institutions, no published study has documented its economic impact. The cost savings of using RAPT must be verified before its widespread adoption for that purpose. However, RAPT potentially provides valuable information to patient and surgeon alike to optimize postoperative expectations. Finally, our study excluded patients younger than 50 yr old because RAPT has not been validated in this population. Thus, RAPT and our model must undergo validation in younger patients before being applied.

CONCLUSION

In this study, we validated the use of RAPT in patients undergoing cervical spine surgery for predicting discharge disposition. We found that RAPT score, RAPT walk score, age, increasing levels operated on, and a posterior approach predicted the need for postacute care facilities on discharge. Additionally, we showed that lower RAPT scores increased the risk of 30-d readmission. Future studies may implement this tool in the surgical setting to inform clinical decisions. They may also evaluate the effect of the adoption of RAPT on rates of discharge to facilities, LOS, and readmission.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Cohen JB, Myckatyn TM, Brandt K. The importance of patient satisfaction: a blessing, a curse, or simply irrelevant? *Plast Reconstr Surg*. 2017;139(1):257-261.
2. Brook RH. Can the Patient-Centered Outcomes Research Institute become relevant to controlling medical costs and improving value? *JAMA*. 2011;306(18):2020-2021.
3. Ackerly DC, Grabowski DC. Post-acute care reform-beyond the ACA. *N Engl J Med*. 2014;370(8):689-691.
4. Delisle DR. Big things come in bundled packages: Implications of bundled payment systems in health care reimbursement reform. *Am J Med Qual*. 2013;28(4):339-344.
5. Welch WP. Bundled medicare payment for acute and postacute care. *Health Aff*. 1998;17(6):69-81.
6. Dauty M, Schmitt X, Menu P, Rousseau B, Dubois C. Using the Risk Assessment and Predictor Tool (RAPT) for patients after total knee replacement surgery. *Ann Phys Rehab Med*. 2012;55(1):4-15.
7. Hansen VJ, Gromov K, Lebrun LM, Rubash HE, Malchau H, Freiberg AA. Does the risk assessment and prediction tool predict discharge disposition after joint replacement? *Clin Orthop Relat Res*. 2015;473(2):597-601.
8. Konopka JF, Hansen VJ, Rubash HE, Freiberg AA. Risk assessment tools used to predict outcomes of total hip and total knee arthroplasty. *Orthop Clin North Am*. 2015;46(3):351-362, ix-x.
9. Oldmeadow LB, McBurney H, Robertson VJ. Predicting risk of extended inpatient rehabilitation after hip or knee arthroplasty. *J Arthroplasty*. 2003;18(6):775-779.
10. Tan C, Loo G, Pua YH, et al. Predicting discharge outcomes after total knee replacement using the risk assessment and predictor tool. *Physiotherapy*. 2014;100(2):176-181.
11. Piazza M, Sharma N, Osiemo B, et al. Initial assessment of the risk assessment and prediction tool in a heterogeneous neurosurgical patient population. *Neurosurgery*. 2018.
12. Slover J, Mullaly K, Karia R, et al. The use of the risk assessment and prediction tool in surgical patients in a bundled payment program. *Int J Surg*. 2017;38:119-122.
13. Davis K, Buttorff C, Leff B, et al. Innovative care models for high-cost medicare beneficiaries: delivery system and payment reform to accelerate adoption. *Am J Manag Care*. 2015;21(5):e349-356.
14. Slover JD, Mullaly KA, Payne A, Iorio R, Bosco J. What is the best strategy to minimize after-care costs for total joint arthroplasty in a bundled payment environment? *J Arthroplasty*. 2016;31(12):2710-2713.
15. Shamji MF, Cook C, Tackett S, Brown C, Isaacs RE. Impact of preoperative neurological status on perioperative morbidity associated with anterior and posterior cervical fusion. *J Neurosurg Spine*. 2008;9(1):10-16.
16. Ashley BS, Courtney PM, Gittings DJ, et al. Can an arthroplasty risk score predict bundled care events after total joint arthroplasty? *Arthroplasty Today*. 2018;4(1):103-106.
17. Niedermeier S, Przybylowicz R, Virk SS, Stammen K, D SE, Khan SN. Predictors of discharge to an inpatient rehabilitation facility after a single-level posterior spinal fusion procedure. *Eur Spine J*. 2017;26(3):771-776.
18. Murphy ME, Maloney PR, McCutcheon BA, et al. Predictors of discharge to a nonhome facility in patients undergoing lumbar decompression without fusion for degenerative spine disease. *Neurosurgery*. 2017;81(4):638-649.
19. Best MJ, Buller LT, Falakassa J, Vecchione D. Risk factors for nonroutine discharge in patients undergoing spinal fusion for intervertebral disc disorders. *Iowa Orthop J*. 2015;35:147-155.
20. McGirt MJ, Parker SL, Chotai S, et al. Predictors of extended length of stay, discharge to inpatient rehab, and hospital readmission following elective lumbar

spine surgery: Introduction of the Carolina-Semmes Grading Scale. *J Neurosurg Spine*. 2017;27(4):382-390.
21. Tanenbaum JE, Lubelski D, Rosenbaum BP, Benzel EC, Mroz TE. Propensity-matched analysis of outcomes and hospital charges for anterior versus posterior cervical fusion for cervical spondylotic myelopathy. *Clin Spine Surg*. 2017;30(9):E1262-E1268.
22. Beaulieu RA, McCarthy MC, Markert RJ, Parikh PJ, Ekeh AP, Parikh PP. Predictive factors and models for trauma patient disposition. *J Surg Res*. 2014;190(1):264-269.
23. Hatcher JL, Bell EB, Browne JD, Waltonen JD. Disposition of elderly patients after head and neck reconstruction. *JAMA Otolaryngol- Head Neck Surg*. 2013;139(11):1236-1241.
24. Crouch DS, McLafferty RB, Karch LA, et al. A prospective study of discharge disposition after vascular surgery. *J Vasc Surg*. 2001;34(1):62-68.
25. London DA, Vilensky S, O'Rourke C, Schill M, Woicehovich L, Froimson MI. Discharge disposition after joint replacement and the potential for cost savings: effect of hospital policies and surgeons. *J Arthroplasty*. 2016;31(4):743-748.
26. Lee L, Schwartzman K, Carli F, et al. The association of the distance walked in 6 min with pre-operative peak oxygen consumption and complications 1 month after colorectal resection. *Anaesthesia*. 2013;68(8):811-816.
27. Fisher SR, Graham JE, Ottenbacher KJ, Deer R, Ostir GV. Inpatient walking activity to predict readmission in older adults. *Arch Phys Med Rehabil*. 2016;97(9):S226-S231.
28. Takahashi T, Kumamaru M, Jenkins S, Saitoh M, Morisawa T, Matsuda H. In-patient step count predicts re-hospitalization after cardiac surgery. *J Cardiol*. 2015;66(4):286-291.
29. Minnella EM, Awasthi R, Gillis C, et al. Patients with poor baseline walking capacity are most likely to improve their functional status with multimodal prehabilitation. *Surgery*. 2016;160(4):1070-1079.
30. Liu CY, Zygourakis CC, Yoon S, et al. Trends in utilization and cost of cervical spine surgery using the national inpatient sample database, 2001 to 2013. *Spine*. 2017;42(15):E906-E913.
31. Sharma M, Sonig A, Ambekar S, Nanda A. Discharge dispositions, complications, and costs of hospitalization in spinal cord tumor surgery: analysis of data from the United States Nationwide Inpatient Sample, 2003-2010. *J Neurosurg Spine*. 2014;20(2):125-141.
32. Fry DE, Pine M, Jones BL, Meimban RJ. The impact of ineffective and inefficient care on the excess costs of elective surgical procedures. *J Am Coll Surg*. 2011;212(5):779-786.
33. Pattakos G, Johnston DR, Houghtaling PL, Nowicki ER, Blackstone EH. Preoperative prediction of non-home discharge: A strategy to reduce resource use after cardiac surgery. *J Am Coll Surg*. 2012;214(2):140-147.
34. Barsoum WK, Murray TG, Klika AK, et al. Predicting patient discharge disposition after total joint arthroplasty in the United States. *J Arthroplasty*. 2010;25(6):885-892.

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COMMENTS

Payment models for care continue to evolve in the face of escalating medical costs. Predictive analytics applied to both the preoperative planning and risk adjustment components of surgical care may help achieve the most efficient postoperative recovery. This particularly applies to spine surgery, in which variability in bundled costs can be high, depending on patient and procedural factors.

Discharge timing and disposition also have significant impacts on episode of care costs.

This study presents an important effort to develop and refine an initial iteration of surgical predictive analytics. The authors applied the Risk Assessment and Prediction Tool (RAPT) towards cervical spine surgery. They prospectively enrolled over 260 patients undergoing elective cervical spine surgery, conducted RAPT assessments, and conducted a comprehensive study of factors that could influence discharge disposition. The RAPT score was helpful in predicting discharge home but could not distinguish between patients who would have different discharge facility needs (acute rehabilitation unit vs skilled nursing facility). Preoperative ambulatory capacity, gender, age, hypertension, hospital length of stay, and the type of surgery were additional factors found predictive of discharge disposition. Of particular interest, this study also included a quality-adjusted life years and cost analysis. Although the RAPT score was not predictive of quality-adjusted life years gained from surgery, it was predictive of overall costs of surgery as well as 30-d hospital readmission.

Further study and utilization of analytic tools such as the RAPT will be important to validate their use by both providers (hospitals and payers) to better predict the appropriate care and cost needs of each individual patient. Discharge disposition is an important determinant of overall bundled cost and requires significant case management coordination to facilitate. It is an eminently targetable preoperative determinant that can help limit in-patient hospital stays and streamline recovery. However, predicting individual patients' postoperative courses following spine surgery may prove to be a more complex and multidimensional endeavor than the RAPT, and careful study and refinement of the tool in as many clinical contexts as possible is prudent prior to truly attaching it as a determinant of expected cost and reimbursement. Finally, as has been done in other industries, incorporation of large patient databases (including the RAPT and a multitude of other preoperative factors) into a machine-learning algorithm may be the best strategy to accurately and reliably model postoperative discharge disposition and overall surgical costs. The current article is an important step towards a better understanding of these relationships.

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The authors reviewed 263 patients to validate the RAPT in a population of cervical spine surgery patients. They have done a good job interpreting their results in the context of previously published work and outlining the limits of their findings in the discussion.

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