Title: Prospective financial modeling for clinical episodes of care: Predicting outcomes and quantifying risk in value-based payment models

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Abstract:

Health systems currently lack a systematic mechanism to evaluate the financial implications of value-based alternative payments. The prospect of assuming an uncertain degree of downside risk is dampening enthusiasm for these payment models and is a barrier to health system engagement. In the context of an episode of surgical care for prostate cancer, we developed a framework for defining a clinical episode of care, analyzing patient-level clinical and financial data, and building a financial simulation model. The purpose of the simulation model is to prospectively quantify the financial implications, including two-sided risk, of transitioning from fee-for-service to an episode-based payment model and the financial impact of modifications in drivers of clinical costs. Furthermore, we highlight practical applications for how stakeholders may utilize this model to facilitate the transition to alternative payment models.

I. Intro:

Fee-for-service (FFS) reimbursement incentivizes maximal use of services without accountability for quality, outcomes, or appropriateness and contributes to low-value care in the United States.(1) Responding to concerns over affordability and quality, stakeholders are intensifying efforts to deploy alternative payment models, including episode-based payments (EBP), which reward high–quality, low–cost care.(2, 3) In an EBP, which is also referred to as a "bundled" payment, an accountable care entity and its physicians receive a lump sum for all medical services within a defined time period or clinical care cycle. Convened by state and federal agencies and commercial payer arrangements, EBP models are increasingly relevant for specialty care providers and surgeons.(4-6)

However, there is much trepidation around this transition to value-based payments. Health systems lack a structured, systematic mechanism to assess how this alternative payment models impact institutional and provider finances.(7, 8) Current strategies estimate health system reimbursement under an alternative model relative to FFS. This method treats "cost" of care as how much the payer reimburses the health system, rather than the true cost to deliver that service. Since true internal costs are neither well-understood nor systematically tied to reimbursement, such analysis provides an incomplete picture of the true financial implications of transitioning from FFS to value-based payment.(9) For health care organizations to engage in more effective care redesign, they must understand the impact of adopting an alternative payment arrangement in the context of true costs to deliver care.(10) Thus far, the uncertain financial implications have stymied stakeholder enthusiasm in alternative payment models.(11)

We propose a health system-driven framework to systematically evaluate the impact of adopting EBP for a discrete clinical episode of care. We illustrate the approach through a case study of prostate cancer surgery at a tertiary academic institution. The objectives are to develop a mechanism to 1) quantify the impact on stakeholder finances of transitioning from FFS to an EBP and to 2) inform value-based care redesign efforts by quantifying the effect of clinical cost drivers on financial outcomes. Herein, we discuss our process for collecting and analyzing episode-specific clinical and financial data, describe our simulation model for predicting financial outcomes, and highlight potential uses of the framework for a surgical episode of care for prostate cancer.

II. Study Data and Methods

A. Episode design and cohort identification

Episode selection

An episode of care may span an inpatient hospitalization, a surgical procedure, or a medical condition (acute or chronic). Broader episode definitions present greater opportunity to address variation and low-value care but introduce complexity in payment administration, billing, defining episode-specific services, and risk-adjustment.(12)

Radical prostatectomy, a surgical procedure involving removal of the prostate, represents the surgical standard of care for localized prostate cancer. This episode satisfies the Health Care Payment Learning & Action Network's criteria for prioritization for value-based alternative payment models, including consumer engagement, high volume/high costs, unexplained variability, defined care trajectory, and available quality measures outlined in Appendix Exhibit A1(13, 14). It is a likely focus for future EBPs.(14, 15)

Define episode period

The closest urology visit prior to surgery initiated the clinical episode, which continued 90 days post-operatively (Appendix Exhibit A2).(13) While many medical and surgical EBP models begin at the index hospitalization(12), we capture variation in pre-operative care to identify opportunities for value improvement during this phase. In the pre-operative period, we include only services rendered for prostate cancer or pre-operative work up according to the diagnosis codes (ICD-9 185.0, ICD-10 C61 and ICD-9 V72.81-V72.84, ICD-10 Z01.810-Z01-818). As this surgery is not urgent, many patients undergo a prolonged pre-operative phase, which may include separate clinical treatments. However, we attribute all medical services during the index admission and 90-day post-operative phase to this episode of care.(16) Appendix Exhibit A3a and A3b(13) reports all procedure codes associated with the relevant diagnosis in the episode time frame and all revenue codes corresponding to inpatient services rendered.

Identify patient cohort

After obtaining Institutional Review Board approval, we identified a cohort of patients undergoing robot-assisted laparoscopic radical prostatectomy in 2016 at the primary teaching facility of a tertiary institution. We utilize the hospital's hybrid analytics and information technology group to extract cases using International Classification of Diseases version 9 or 10 (ICD-9 or ICD-10) codes for prostate cancer (185.0 or C61, respectively) and Common Procedural Terminology code for laparoscopic radical prostatectomy (55866). This group provides reporting, analysis, monitoring and actionable business intelligence by combining data across different hospital systems. We cross-referenced the cohort with operative schedules to assure the veracity of our search. We identified N = 157 cases performed by five faculty.

Define value-based care pathway

Participating urologic oncologists created a process diagram of all services that may occur during the pre-operative, intra-operative, peri-operative, and post-operative phases of care for prostate cancer surgery at our institution (Appendix Exhibit A4)(13). This represents the spectrum of clinical practices among the five urologic oncologists who perform this procedure and a serves as a starting point to discuss care optimization.(17) Wherever possible, we include true internal costs for delivering each individual service based on prior institution-specific cost analyses.(18) After compiling the inclusive care pathway, research staff interviewed each urologist for a consensus on which services constitute value-based care based on physician experience, knowledge, and preference. For each service, we asked the urologists to answer whether it should be included in an EBP model where the health care entity received a lump sum for all services rendered during the episode. We identify consensus for high- and low-value services when at least four of the five agreed that it did or did not add value, respectively. We identify services about which providers did not express consensus (two providers disagreed with the other three). Research staff conducted subsequent interviews to determine the reason for disagreement for each of these services and identified available quality or cost-effectiveness literature related to that service to help resolve disagreement. We used this process to inform modifiable clinical parameters in the model. (Appendix Exhibit A5.B)(13)

B. Obtain Empirical Demographic, Clinical and Fee-for-Service Financial Data

Demographic and Clinical Data

Our bioinformatics team extracted relevant demographic and clinical data, including patient age, body mass index, comorbidities, education and income, and tobacco use, as well as tumor grade and stage. We also abstracted clinical data from the inpatient admission, including length of stay, operating room time, escalation of care, and post-discharge events, including discharge disposition, readmissions, and emergency room visits. (Appendix Exhibit A6)(13)

Financial Data

After identifying our cohort and defining our episode, we obtained granular cost and reimbursement data for each case. Exhibit 1 reports aggregate financial input data and Appendix Exhibit A7(13) provides additional detail on the cost-accounting methods and data sources. Despite a mix of payers, we calculated reimbursement according to Medicare fee schedules to simulate a Medicare-specific EBP model. The confidential nature of commercial contracts preclude inclusion in this report, however we previously verified the assumption that costs are independent of payer.(19)

Costs

We separate costs by phase (pre-operative, inpatient, post-operative). We further separate out pre-operative imaging costs (chest radiograph, electrocardiogram, and prostate MRI) from other pre-operative costs, as these are easily modifiable cost inputs and simple targets for value-based care redesign. Of note, the vast majority of cardiac stress tests were performed outside of our institution, so these were not included in our simulation model. We further divided inpatient costs into two phases: surgery/peri-operative and inpatient ward (personnel and hospital). We utilize previously-reported time-driven activity-based costing estimates for outpatient (all costs) and inpatient (personnel costs only) for robotic radical prostatectomy at our institution.(18) For all other operating room/peri-operative and inpatient ward costs, we use data from the hospital's activity-based costing system (Appendix Exhibit A7).(13)

Reimbursement

We also separated reimbursement by phase (pre-operative, inpatient, post-operative) and type (professional, non-professional). Non-professional reimbursement included the Inpatient Prospective Payment System's reimbursement for laparoscopic radical prostatectomy (CPT code 55866), with or without pelvic lymph node dissection (CPT code 38571), and technical component reimbursement for non-professional outpatient services such as radiology and laboratory testing (Appendix Exhibit A3a).(13) We searched the publically available Medicare Physician Fee Schedule to calculate patient-level professional reimbursement estimates for all outpatient and inpatient physician services, excluding anesthesia.(20) Due to unique and complex contracting considerations for anesthesia reimbursement at our institution, we obtained per-case Medicare payment estimates directly from their finance office. In our simulation model, anesthesia reimbursement only affects the outcome in the FFS scenario, and only to a very small degree.

C. Episode payment model design

We develop an EBP model by defining financial and clinical parameters that can be modified according to the specifics of the clinical episode and model participants.(7, 12, 17, 21-23) Key model components are provided in Exhibit 2. We describe the EBP payment calculations for all participants in Appendix Exhibit A5(13).

D. Financial simulation model

We construct a simulation to gain confidence in the computation of stakeholders' payments under the EBP model. This entails sampling patient cohorts consistent with individual patient-level empirical cost and clinical data from our initial population to compute payment distributions under an EBP arrangement and the extant FFS model. We build the simulation model using the following steps:

Step 1: Identify and extract empirical patient-level clinical and granular financial data inputs (Exhibit 1 and Appendix Exhibit A6)(13) for the original patient cohort.

Step 2: Independently fit distributions for each empirical data input. We evaluate the fit of the following distribution types: Normal, Beta, Gamma, Gumbel, Lognormal, and Triangle. For each component-distribution pair, we use the MLE method of the function *fit* from the R package *fitdistrplus* to generate distribution shape and scale parameters. Then, we perform Cramer von Mises non-parametric test to determine p-values of similarity between true distributions and select the best fit. For binary input variables, we fit a Bernoulli distribution. The best fit distributions are available in Appendix Exhibit A8(13).

Step 3: Obtain correlations between input variable pairs based on the empirical cohort data. Using these correlations, we generate patient data that is consistent with the empirical cohort. Appendix Exhibit A9(13) depicts the correlogram between variables.

Step 4: Generate input data for a simulated patient cohort. We sample each individual patient's cost, resource utilization and FFS reimbursement input variables from the fitted distributions, taking into account the correlations among input variables. In this way, simulated data accurately represents the original patient cohort, so that if, for example, a patient's sampled resource utilization is high (e.g., long length-of-stay), the corresponding sampled hospital cost appropriately reflects this resource utilization. We assume individual patients are independent of each other and use the Cholesky matrix decomposition technique to add desired correlation to independently drawn data. For simplicity, we account for primary correlations and ignore cascading effects. For example, we correlate total length-of-stay with diagnosis-related group code, but not diagnosis-related group code with post-operative cost. The latter is captured through the correlation between total length-of-stay and post-operative cost. This approach allows us to replicate most correlations that are above 0.3 (below -0.3) in the simulated data. We validate simulated data by graphically comparing empirical (original cohort) and simulated distributions for independent input variables in Appendix Exhibit A10.(13)

Step 5: Calculate payment distribution. Using the simulated patient cohort data, we calculate the relevant financial outcome for each stakeholder according to the defined EBP model described above. The corresponding outcomes include the per-episode payment (provided by the payer), the per-episode financial margin (accountable entity and hospital), and per-episode payment (received by the physician). We also compute corresponding hypothetical FFS payments using the sampled reimbursement data for each patient. By generating many patients cohorts (>200) and calculating the corresponding payments under EBP and FFS, we generate the distribution of payments for each stakeholder and payment model. Based on these distributions, we report statistics and risk metrics using the status quo (median FFS simulated payment) as a benchmark.

E. Risk Evaluation:

In evaluating the adoption of the EBP model, we consider financial outcomes not only by the expected financial performance, but also in terms of the level of financial risk assumed by each stakeholder. To quantify payment volatility, we compute the payment standard deviation over the simulated patient cohorts for both the EBP and FFS. However, this aggregate volatility measure does not allow us to quantify risk in terms of best- and worst-case scenarios. Therefore, we consider two additional financial risk metrics inspired by the Value at Risk and Conditional Value at Risk, to communicate pertinent risk of the EBP model (Appendix Exhibit A11).(13) Using the median FFS payment as a benchmark, we compute the probability that a stakeholder is better off under EBP and the expected gains (losses) given that the stakeholder performs better (worse) in the EBP model (Conditional Value at Risk). Essentially, the latter measure illustrates the expected two-sided "risk-corridor" that each stakeholder faces when deciding on entering the EBP.

III. <u>Study Results</u>

We created a web-based, user interface for the financial simulation that allows stakeholders to modify financial and clinical input parameters and dynamically evaluate financial outcomes under a range of payment model and clinical scenarios for the episode of care (Appendix Exhibit 12).(13) The following case studies demonstrate two potential applications of our financial model.

A. Case study 1: Financial implications of transitioning from fee-for-service to episode-based payment (Exhibit 3)

For this application, we maintain the modifiable clinical parameters at their baseline levels (Exhibit 1 and Appendix Exhibit A5.A and A5.B) to represent the current state clinical care and existing cost structure from our empirical cohort, including annual case volume. We display the payment outcome under EBP for a cohort of simulated patients as a percentage change from the median FFS payment for each stakeholder. Positive (negative) change compared to the median FFS reflects a more (less) favorable outcome for that stakeholder.

For our baseline EBP model, we set the episode price at the historical mean institutional payment. Federal bundled payment programs frequently mandate a downward adjustment (often around 3%) to ensure savings to the payer, we elected to maintain the episode price at the historical mean for this example and therefore set this adjustment factor to zero.(12) We set the upper limit of aggregate shared savings (losses) for the accountable entity at 20% (8%) of mean episode cost and the individual stop-loss threshold at 3 standard deviations above the mean.(22) The flat physician fee for the episode of care reflect publicly available Medicare reimbursement rates with the physicians and the hospital evenly splitting any shared savings or losses incurred by the accountable entity. We set the percent chance that the accountability entity meets the minimum quality threshold and is eligible for shared savings at 100%. We ran 200 cohorts of 160 simulated patients (estimated annual case volume) through the financial model in order to generate adequate statistical confidence in our results. Exhibit 3 shows the per-patient financial outcome under the EBP (baseline) model relative to the median FFS payment.

When evaluating median outcomes under this baseline EBP model, the payer and physicians are likely to fare slightly better compared to FFS. Conversely, the model predicts an unfavorable outcome for the accountable entity, which is driven by a decrease in the hospital's margin. We quantify the likelihood of each stakeholder faring better under the EPB in the third row of the table. The table's fourth and fifth rows quantify the change in payment or margin for each stakeholder given that they perform better or worse under the EBP relative to the FFS benchmark. These percentages quantify the expected limits of upside and downside risk for that stakeholder under the given EBP parameters. Note that while the median payment for physicians is greater under the EBP, they also assume greater downside risk for high-cost patient outliers.

There is no prescriptive “correct” level for any of the financial payment model parameters selected above. Importantly, our model allows stakeholders to explore the entire spectrum of options, potentially in the context of an EBP contract negotiation. For example, we adjust the EBP parameters to shift more downside risk onto the payer by reducing the accountable entity’s maximum aggregate loss from 8% to 5% and lowering individual patient outlier threshold from three to two standard deviations above the mean. The percentage change from FFS and likelihood that stakeholders fare better or worse under this EBP becomes more equitable compared to the baseline EBP scenario (third box plot vs second box plot).

B. Case study 2: Impact of modifying individual clinical cost drivers on financial outcomes in an episode-based payment model

Here we assume that all stakeholders have entered into an EBP model with the baseline financial parameters. We now use the financial model to explore how changes in clinical cost drivers (Appendix Exhibit A5.B)(13) affect financial outcomes for each stakeholder. This application helps inform value-based care redesign efforts by prospectively evaluating the financial impact of changes in resource utilization, efficiency, and outcomes that drive additional costs. This process also illustrates the business case for aligning stakeholders around value.

Exhibit 4 quantifies the financial outcomes of reducing pre-operative MRI utilization from 35.7% (current state) to 20%, reducing operating room time by 5%, reducing pre-operative cost variation by 50%, and reducing high cost outliers from 3.2% (current state) to 1% within the EBP. The benefit of these modifications is largely enjoyed by the hospital, with a simultaneous smaller improvement in median payment for the payer. Meanwhile, physician payments remain stable with fewer negative outliers compared to the current clinical state. Appendix Exhibit A13(13) reports the progression in payment change and risk measures for each stakeholder.

IV. Discussion

We describe our institutional framework for systematically analyzing a discrete episode of care in the context of an EBP. We outline our financial simulation based on patient-level empirical cost, reimbursement, and clinical data that capture variability in patient care. Through our prostatectomy case study, we demonstrate potential insights into 1) the financial impact of transitioning from FFS to EBP models, and 2) the relative financial impact of value-based care redesign targets. Health systems currently lack such systematic, prospective modeling to anticipate the financial implications of value-based payment reform, make decisions on adopting alternative payments, and maximizing the value of care they deliver.

Our framework fills a number of knowledge gaps and could address strategic hurdles impeding stakeholder engagement with value-based payment models. First, our granular, internal cost accounting methods disentangle the arbitrary relationship between reimbursement and actual costs of delivering specific services.(10) Due to the inherent challenges of obtaining this data, episode “costs” are traditionally viewed from the payer perspective in the form of price-standardized Medicare spending. By comparing historical Medicare spending against prospective financial targets, health systems may estimate short-term reimbursement in an alternative payment model relative to the status quo. However, this strategy lacks the specificity to inform care redesign that maximizes value. We demonstrate how analyzing internal service-line costs relative to reimbursement provides a greater understanding of the financial implications of transitioning away from FFS. This model may also help health systems succeed under value-based alternative payment models by identifying the most efficient targets for value-based care redesign.(10)

Second, we present a novel mechanism to evaluate the financial risk of transitioning from FFS to EBP. Stakeholders remain hesitant to assume uncertain downside risk, hindering adoption of value-based payment models.(11) While the prospect of shared saving and bonus payments incentivize providers to consider qualified alternative payment models, behavioral economics research shows that loss aversion may be a stronger motivator.(24) Therefore, while provider incentive programs may effectively leverage this principle to drive provider behavior change, the specter of significant revenue loss may be a stronger deterrent. This resonates prominently with specialty providers if they perceive excessive costs and poor outcomes as outside of their immediate control. Our model quantifies the expected financial outcomes for each stakeholder, including measures of risk and uncertainty, assuming an array of clinical circumstances and payment model structures. This output, which we display visually and numerically, is both a method of analysis and a tool for communicating uncertainty and opportunity.

Finally, our user interface facilitates stakeholder engagement with value-based payment models. Clinician leaders can tailor relevant clinical cost drivers for specific episodes of care. Stakeholders may participate in payment model design and negotiation by adjusting the financial model parameters to evaluate the impact on financial outcomes. Extrapolated over a particular period for an expected case volume, the payer can project the global change in service line spending, the risk-bearing entity can project the global change in profit margin, and the provider can estimate the overall change in reimbursement for that episode. The health system can also use this model to calculate the expected return on investment of value-improvement initiatives.

We note several important limitations. First, while quality measures are critical to any discussion of value, our financial model focuses primarily on cost. Defining feasible, pertinent, and specific measures of quality and patient experience that occur within the appropriate time, are adequately risk-adjusted, and under the control of those at risk, remains challenging.(25, 26) Furthermore, incorporating these measures into predictive modeling is even more complicated. To acknowledge the importance of quality, we created a modifiable parameter representing the likelihood in a given year that the accountable entity meets a generic minimum quality standard.

If this minimum threshold is not met, the entity is ineligible for gain-sharing.(17) Specific quality metrics, methods of data collection, and minimum quality thresholds may vary across service line and institution, but must be clearly delineated at the outset.

Second, from the health system's global budget perspective, the actual financial impact of this individual service line is negligible and the insights generated by our prototype are only valid internally. However, this prostatectomy financial model serves as a learning case through which we developed a replicable, scalable framework to evaluate and improve the value of individual care episdoes. This model is a mechanism to facilitate the transformation from volume to value. If health care organizations can operationalize the ascertainment of accurate, granular cost data, they could internally scale this analytic process to drive a profound, system-wide transformation to higher-value care. The University of Utah, for example, recently implemented a systematic cost-accounting system that provides necessary data inputs to scale this financial modeling work. (27)

Third, this financial model addresses only variable or marginal costs. Many experts and health system managers view cost-savings attributed to reduced utilization at the margin as a "savings illusion" due to the massive fixed costs.(28) However, others argue that within the appropriate time frame and with adequate managerial attention, up to 95% of healthcare costs may be considered variable.(10) This emphasizes the need for system-wide scaling of this methodology in conjunction with an active, institutional commitment to redesigning delivery systems.

Finally, this tool is not a stand-alone solution to value transformation. Rather, it provides insights and actionable information that supports value-based care initiatives, clinician engagement, and EBP design that align payers, hospitals, and physicians around high-value care.(29) For example, our institution employs a dedicated value-based care redesign team that directly engages with clinicians. We are developing a multidisciplinary initiative comprised of clinicians, health services researchers, hospital operations and finance leaders, information technology experts, and business school faculty to scale this framework within our system. Armed with the model's data-driven insights, the care redesign team can prospectively identify the highest-impact value-based care targets, estimate the benefits of value-improving initiatives, and more effectively communicate the business case for improving value to front-line clinical partners. Critical to this task are information technology solutions that automate episode selection, patient attribution, data collection, and analysis, including longitudinal analyses of redesigned service lines.

V. **Conclusion:**

The transformation to value-based care in the United States faces many profound challenges. While societal, political, economic, and psychological barriers continue to impede the transition, health systems are forging ahead with efforts to design and implement alternative payment models, driven both by commercial and public payers. We present the details of our systematic framework for prospectively generating institution-specific financial insights into the value of care delivery for defined episodes. Importantly, this model allows stakeholders to better understand the financial risk of adopting alternative payment models. However, this process must be replicated, validated, operationalized, and scaled on the health system level in order to effectively contribute to systematic delivery system redesign.

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Exhibit List:

EXHIBIT 1 (table)
Caption: Model Input Variables: Empirical Cohort Data
Source/Notes:

SOURCE [Authors' analysis of institutional data]

NOTES [Abbreviations: CXR – chest x-ray, EKG – electrocardiogram, LOS – length-of-stay, MRI – Magnetic resonance imaging, MS-DRG – Medicare severity diagnosis related group

[a]Length-of-stay outliers defined as greater than two standard deviations above the mean length-of-stay

[b]All patients were discharged home. Nine patients with nine emergency department visits and four readmissions. In our financial model, we elected not include post-acute encounters as an input variable and instead modeled cost outliers based on length of stay. Because of how infrequently post-acute care occurred, no other variable correlated with post-acute costs/reimbursements and was therefore not useful for the model. This also explains the very large standard deviations.]

EXHIBIT 2 (table)
Caption: Episode Payment Model
Source/Notes:

SOURCE [Authors' analysis of institutional data and MITRE Corporation. Contracting for bundled payment Dec 16, 2011.]

NOTES [[a]For this episode of care, there were very few clinical outcomes that deviated from the optimal care pathway, including no escalations of care to a higher acuity inpatient unit, no discharges to an institutional post-acute care facility, 13 emergency department visits (8.3%) and four readmissions (2.5%). There were no pre-operative variables that predicted these deviations, so we therefore collapsed all of these potential sources of outlier costs into a single parameter (prolonged length of stay) for modeling purposes.]

EXHIBIT 3 (Figure)
Caption: Expected change in payment under different episode-based payment models compared to status quo fee-for-service

Source/Notes:

SOURCE [Authors' analysis of simulated data]

NOTES [Abbreviations: EBP – episode-based payment, FFS – fee-for-service, H-P – hospital-physician]

EXHIBIT 4 (Figure)

Caption: Expected change in payment under different episode-based payment models compared to status quo fee-for-service

Source/Notes:

SOURCE [Authors' analysis of simulated data]

NOTES [Abbreviations: EBP – episode-based payment, FFS – fee-for-service, H-P – hospital-physician, MRI – magnetic resonance imaging, OR – operating room]

Exhibit 1:

	Input Variable	Mean	SD
Phase I: Pre-operative	Cost pre-operative (excluding imaging) ($)	449	344
	Cost MRI ($) Probability of receiving MRI	670 35.7%	- -
	Cost CXR ($) Probability of receiving CXR	20 14.0%	- -
	Cost EKG ($) Probability of receiving EKG	20 24.2%	- -
	Reimbursement pre-operative ($)	1380	1087
Phase II: Inpatient	% DRG 707 (708)	15.3% (84.7%)	-
	Cost of surgery and peri-operative care ($)	3979	592
	Personnel costs in ward ($)	1554	1006
	Cost of inpatient hospitalization ($)	13546	4007
	Reimbursement hospital ($)	16,773	1803
	Reimbursement professional ($)	2615	506
	Reimbursement anesthesia ($)	545	81
	Total length-of-stay, non-outliers (days)	1.56	0.60
	Total length-of-stay, outliers[a] (days)	5.68	1.42
	Operating room time (min)	259	49
Phase III: Post-operative	Cost post-operative ($)	147	137
	Cost post-acute care[b] ($)	234	1416
	Reimbursement post-acute care[b] ($)	313	1857

Exhibit 2:

Financial Parameters	Elements of the financial model
Episode payment	• Target or “bundle” price reimbursed per episode by the payer • May be further adjusted based on negotiated discount factors and patient risk profiles
Allocation of risk: Payer and accountable entity	• Shared savings – upper limit of any financial savings awarded to accountable entity (payer retains any remaining savings) • Risk-bearing – upper limit of any financial losses borne by the accountable entity (payer bares any additional losses) • Stop-loss threshold – upper limit of costs for an individual episode above which the payer assumes financial responsibility
Allocation of risk: Parties within accountable entity (hospital and physicians)	• Shared savings – upper limit of any financial savings awarded to physicians (hospital retains any remaining savings) • Risk-bearing – upper limit of any financial losses borne by the physicians (hospital bares any additional losses)
Quality threshold	• Annual probability of the accountable entity reaching a pre-determined, episode-specific, minimum quality threshold • Ensures reduced costs to not come at the expense of care quality • Accountable entity is only rewarded shared-savings if this quality threshold is met
Clinical parameters	Clinical cost drivers
Case volume	• Number of episodes per year
Efficiency	Reflects clinical care processes and pathways • Operating room time • Hospital length of stay
Resource utilization	Reflects how intensely medical services and supplies are utilized • Pre- and post-operative cost variability • Pre-operative advanced imaging (prostate MRI) • Operating room costs, per minute (reflects supplies used) • Inpatient ward costs, per minute (reflects intensity of inpatient care)
Outcomes	Reflects clinical outcomes that deviate from optimal care pathway • Prolonged length of stay[a]

Appendix Exhibit A1 - Criteria for episode selection

Criteria	
Empower consumers	The decision to undergo prostate cancer treatment is highly preference sensitive and provides an opportunity for patient engagement through shared decision-making.(1)
High volume, high cost	With 175,000 new cases of prostate cancer diagnosed in the United States in 2019 urologists perform more radical prostatectomies than any other major urologic oncology operation, both in the community and in academic medical centers.(2)
Unexplained Variation	The degree to which clinicians and health systems adopt advanced technologies in the surgical management of prostate cancer varies greatly, resulting in widely discrepant national price-standardized Medicare payments (range $7,046 - $40,687), for radical prostatectomy not explained by patient severity (Ellimootil, urology 2018. Variation in Physician-Specific Episode Payments for Major Cancer Surgery and Implications for the Merit-Based Incentive Program).(3, 4) These technologies include surgical robots, magnetic resonance imaging, and genetic biomarker assays. In addition, differential physician payments, readmission rates and utilization of post-acute care sustain this variation even when adjusting for systematic cost structure differences.(5, 6)
Defined care trajectory	The fundamental care pathway for radical prostatectomy is well-defined and fits into the American College of Surgeons Surgical Phases of Care conceptual framework (pre-operative, surgical, peri-operative, and post-operative). (https://www.facs.org/advocacy/quality/phases) While the steps within each phase have institution and provider-specific nuances, clinicians, administrators, and payers easily recognize the initiation and termination of the episode and the services attributable to the episode of care.
Available quality measures	Generic quality measures (including process and outcomes) outlined by the American College of are applicable to this care episode. Both the American Urological Association and the National Surgical Quality Improvement Program have established surgery-specific quality metrics. Furthermore, professional urologic societies, including the American Urological Association and the Large Urology Group Practice Association, have been actively pursuing federal episode-based payment model proposals for radical prostatectomy and prostate cancer care, with limited success.(7, 8)

Adapted from: Accelerating and Aligning Clinical Episode Payment Models, MITRE Corp 2016.

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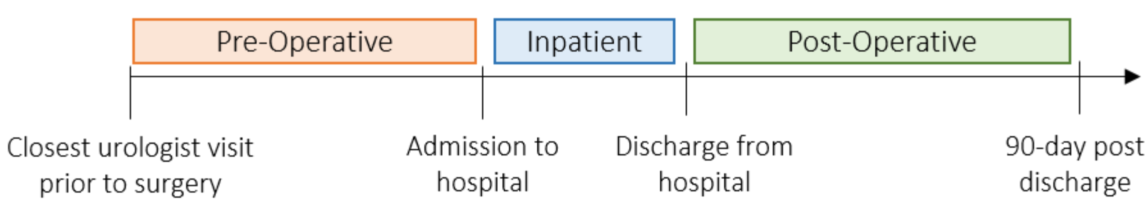
8. Kapoor DA, Shore ND, Kirsh GM, et al. The LUGPA Alternative Payment Model for Initial Therapy of Newly Diagnosed Patients With Organ-confined Prostate Cancer: Rationale and Development. Reviews in urology. 2017;19(4):235.

Appendix Exhibit A2: Episode of care for robotic radical prostatectomy



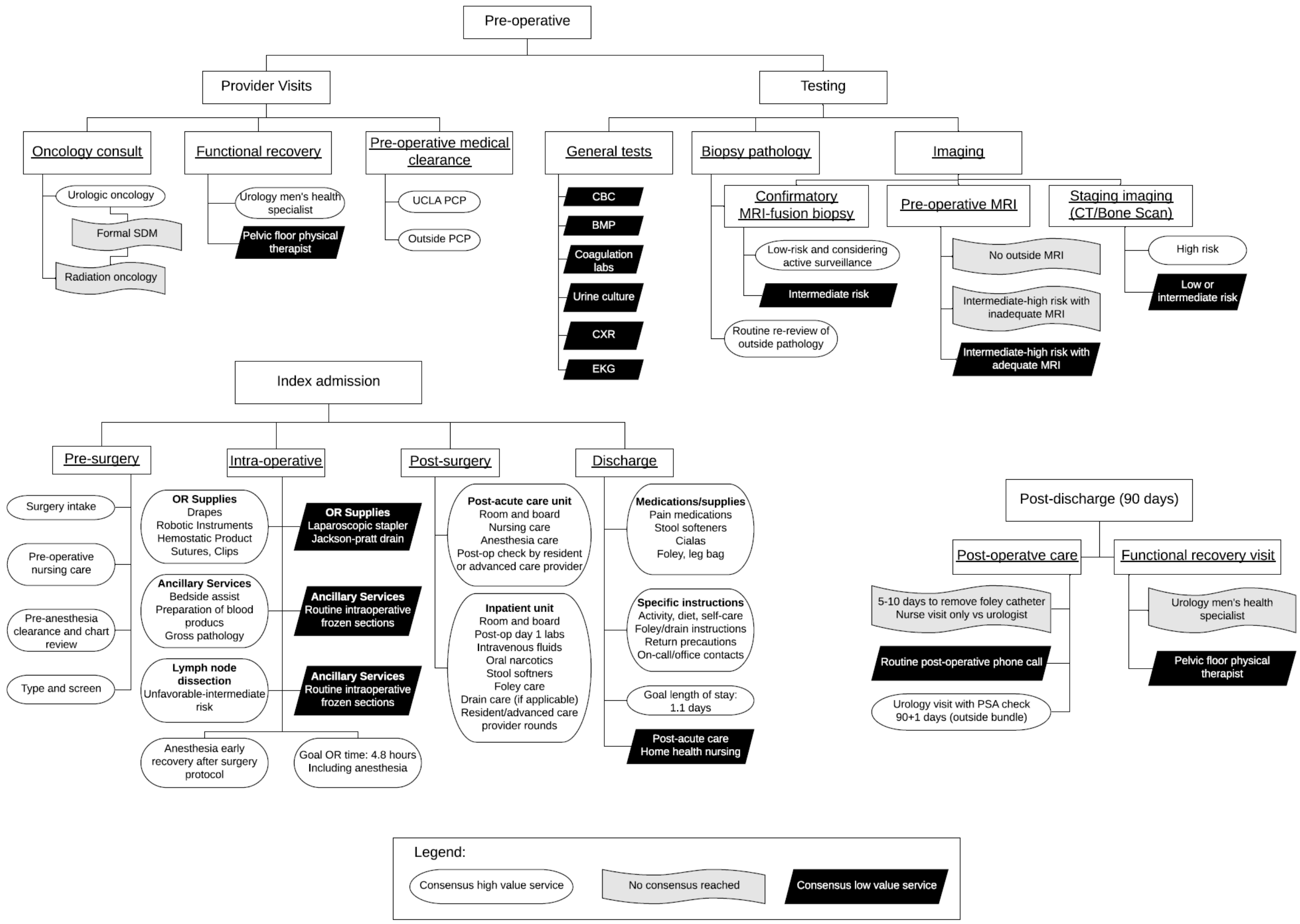
Appendix Exhibit A3a: Current procedural terminology codes for outpatient services, supplies, and medications during episode

CPT Category I	**CPT codes**
Surgery (10000-69990) Integumentary system (10040-19499) Musculoskeletal system (20000-29999) Respiratory system (30000-32999) Cardiovascular system (33010-37799) Digestive system (40490-49999) Genitourinary system (50010-55980) Nervous system (51000-64999) Auditory system (69000-69979)	 11100, 11101, 11721, 13121, 15852, 17004, 17263, 17311, 17312 20220, 20550, 20605 31231, 31500, 31575, 31579, 31624, 31629, 31633, 31645, 31652 36011, 36415 46600, 49185, 49406, 49423, 49440, 49505 50200, 51600, 51700, 51701, 51702, 51703, 51736, 51741, 51798, 52204, 52281, 52310, 54220, 54230, 54235, 55700, 55876 64612 69210
Radiology (70000-79999)	70480, 71010, 71010, 71020, 71250, 71260, 71275, 71555, 72040, 72100, 72148, 72192, 72195, 72196, 72197, 72220, 73030, 73502, 73630, 73725, 74000, 74020, 74022, 74175, 74176, 74177, 74178, 74183, 74220, 75561, 75565, 75984 76000, 76140, 76376, 76377, 76700, 76705, 76770, 76755, 76872, 76873, 76942, 77012, 77080, 77263, 77280, 77290, 77295, 77301, 77332, 77334, 77338, 77435, 77470, 78306, 78264, 78452, 78472, 78579, 78580, 78815, 93980
Pathology and Laboratory (80000-89398)	80048, 80051, 80053, 80076, 81000, 81001, 81002, 81015, 82247, 82270, 82306, 82330, 82550, 82565, 82570, 82607, 82670, 82728, 82746, 82947, 82962, 83002, 83036, 83540, 83550, 83605, 83735, 83880, 84100, 84153, 84154, 84165, 84403, 84443, 84484, 84520, 85014, 85018, 85025, 85027, 85046, 85060, 85097, 85610, 85730, 86334, 87040, 87077, 87086, 87088, 87186, 88112, 88161, 88173, 88189, 88291, 88302, 88304, 88305, 88311, 88312, 88313, 88321, 88323, 88333, 88341, 88342, 88344, 88368, 88377
Medicine (90281-99099; 99151-99199; 99500-99607)	90471, 90472, 90474, 90656, 90662, 90670, 90686, 90688, 90690, 90715, 90732, 90736, 92004, 92012, 92014, 92015, 92083, 92133, 92225, 99245, 92250, 92275, 92504, 92524, 92612, 92613, 93000, 93005, 93010, 93015, 93306, 93321, 93351, 93352, 93458, 93880, 93970, 93971, 93976, 94010, 94726, 94729, 95886m 95912, 96365, 96366, 96367, 96372, 96402, 96413, 97140, 97810, 99000, 99024
Evaluation and Management (99201-99499)	99051, 99203, 99204, 99205, 99211, 99212, 99213, 99214, 99215, 99220, 99221, 99222, 99223, 99232, 99233, 99238, 99239, 99242, 99243, 99244, 99245, 99254, 99255, 99283, 99284, 99285, 99291, 99292, 99306, 99309, 99310, 99356, 99386, 99396, 99397, 99469, 99999
Other	0399T
CPT Category II	
Patient management Patient history Diagnostic/Screening Therapeutic, preventive or other interventions	0521F 1101F, 1111F, 1125F, 1126F 3725F 4044F, 4046F
Healthcare Common Procedure Coding System – including supplies and medications	A4209, A4213, A4218, A4322, A4338, A4351, A4353, A4434, A4930, A5112, A9502, A9503, A9541, A9552, A9577, E0325, G0416, G0438, G0439, G0477, J0585, J0696, J1100, J1200, J1561, J1720, J2405, J2505, J2785, J3301, J7050, J9171, J9217, J9999, Q9957, Q9967, S0020, S1015

Appendix Exhibit A3b: Revenue codes for inpatient services

Revenue Center	Revenue Codes
Laboratory/Blood bank	300, 301, 302, 305, 306, 390, 391
Pathology	310, 312, 314
Radiology	320, 324, 352, 402
Pharmacy	250, 258, 259, 636, 637
Operating room	360, 361, 370
Room/board	111, 130, 206, 710, 761
Medical/surgical supplies/devices	272, 278
Other inpatient services	410, 412, 420, 424, 429, 460, 483, 730, 771, 921
Diagnosis Related Group	707, 708

Appendix Exhibit A4: Prostatectomy value-based work flow



Appendix Exhibit A5: Episode payment model input parameters

A. Financial input parameters

Modifiable Payment Model Variables		
Parameter	Baseline value	Description
N (patients)	160	Patient cohort size
TargetPrice ($)	20,600	Raw $ amount paid to the entity per patient per episode of care. Value corresponds to mean reimbursement in original cohort, including hospital and professional amount
% RiskAdj	0%	Risk adjustment to TargetPrice to account for population risk
% PriceAdj	0%	Price adjustment to TargetPrice to account for entity-payer negotiation outcome
n	3 SD	Number of standard deviations that define a cost outlier patient for payment
GainFactor	20%	Multiplicative factor of historical patient cost used to define maximum entity gain
LossFactor	8%	Multiplicative factor of historical patient cost used to define maximum entity loss
% GainShare	50%	Portion of entity's gain received by physician group
% LossShare	50%	Portion of entity's loss assigned to physician group
PFFS	2,344	Fee per patient paid to the physician by the hospital. It corresponds to the mean reimbursement in original cohort
Bonus	0%	Indicator variable that takes value 1 if physician group qualifies for 5% profit bonus
QualityTarget	100%	Probability the entity meets quality target

Abbreviations: PFFS – physician's (urologist) fee-for-service

B. Clinical input parameters

Modifiable Clinical Input Variables		
Parameter	Baseline value	Description
Probability MRI	35.7%	Based on original cohort
Proportion LOS patient outliers	3.2%	Based on original cohort
LOS adjustment	100%	Multiplicative scaling of LOS
OR time adjustment	100%	Multiplicative scaling of OR time
Cost per minute in operating room	12.07	Estimated from original cohort
Cost per minute in inpatient ward	0.733	Estimated from original cohort
Variability (SD) pre-operative cost	0.667	Standard deviation of log pre-operative cost
Variability (SD) post-operative cost	0.60	Standard deviation of log post-operative cost

Abbreviations: CXR – chest x-ray, EKG – electrogardiogram, MRI – magnetic resonance imaging

C. EBP Model Parameters

I. Episode Payment

This is the amount paid to the accountable entity per patient for the entire episode of care. The final amount is the result of entity and payer negotiation, and often reflects historical entity-specific payments for standard episode-related services and/or a combination of entity specific and regional benchmark reimbursements.(1) We set an initial *Target Price* as the historical average payment for all services included as part of the episode; for example, we consider the weighted average of DRG payments, physician fee-for-service reimbursement for inpatient and outpatient care, and outpatient medical services (technical component reimbursement). We additionally included adjustment parameters in the financial model to anticipate changes in population risk and price negotiation between the entity and payer, namely:

- Entity Risk Adjustment (*% RiskAdj*): To account for relative increases in expected costs due to patient risk factors.
- Episode Price Adjustment (*% PriceAdj*): To account for changes in the episode price. This could reflect payer-mandated discounting and/or changes due to entity-payer negotiation.

Thus, the per patient per episode payment is defined as

$$EpisodePrice = Target\ Price \times (1 + \%\ RiskAdj) \times (1 + \%\ PriceAdj)$$

II. Risk-sharing parameters: Between payer and accountable entity

Stop-loss threshold

One method to mitigate downside financial risk to the accountable entity is to implement a patient-level cost threshold, above which the payer assumes financial responsibility for excessive costs. We define *CostThreshold* as *n* standard deviations above the historical mean cost per an episode. The value of *n* must be determined in the negotiation process between the payer and the accountable entity. Then, for a cohort of N patients, where each patient realizes episode cost $PatientCost_i$, the payer covers the additional costs across all patients, namely:

$$OutlierCost = \sum_{i=1}^{N}(PatientCost_i - CostThreshold)^+$$

III. Shared savings and risk-bearing

Savings (gains) are defined as the difference between the expected cohort payment (*EpisodePrice x* N) and actual cohort costs. We elected to model out a scenario where the accountable entity receives 100% of first-dollar savings up to a specific threshold (percentage above the historical cost mean) with the payer keeping any gains beyond the threshold. Similarly, when costs exceed the target episode price for the cohort (losses), the accountable entity is responsible for 100% of first-dollar losses up to a defied percentage below the historical mean. The payer is responsible for losses beyond that threshold.[1]

$$GainThreshold \ = \ GainFactor \times \ N \times \ Mean\ PatientCost$$
$$LossThreshold \ = \ LossFactor \times \ N \times \ Mean\ PatientCost$$

Where *GainFactor* and *LossFactor* capture the magnitude of the gain and loss thresholds, respectively, relative to the cohort average cost. We note, however, that in order to receive any shared savings, the entity must meet minimum episode-specific quality targets.

IV. Risk-sharing parameters: Parties within accountable entity

Shared savings and risk-bearing

Gains and losses generated by the accountable entity are split among the distinct parties that comprise the accountable entity. In our case, we model a two party entity (physicians and hospital), however a similar approach can be extended to entities made up of additional parties. The following parameters define how gains and losses are allocated within the entity. These parameters are suitable for negotiation between parties and should be agreed upon at the outset.

[1]In practicality, savings and losses may be shared between the payer and the accountable entity in any number of ways, including distributing them proportionally between the payer and entity. This allocation must be agreed upon entering into an episode-based payment model and may vary widely. For example, the accountable entity may prefer to minimize downside risk in exchange for a more limited portion of shared savings, or conversely accept full downside risk in exchange for retaining all potential savings.

D. Financial outcomes

We define stakeholders net payment for a cohort of N patients. In the result section, we present outcomes on a per-patient basis, which is obtained by simply dividing the computed stakeholder payment by the cohort size N.

I. Accountable entity: For a given patient cohort, we first derive the total episode treatment cost after accounting for the outlier cost threshold as

$$TotalCost \; = \sum_{i=1}^{N} \min\{PatientCost_i, CostThreshold\}\,.$$

We can then define the entity's episode financial margin as the total episode payment for the entire cohort net of total cost, after accounting for outliers. Gains, or savings, occur when payments are higher than costs, while costs that exceed the episode payments translate into losses.

$$TotalGain \; = (N \times EpisodePrice - TotalCost)^{+}$$
$$TotalLoss = (TotalCost - N \times EpisodePrice)^{+}$$

The above quantities are shared between the entity and the payer according to the amounts dictated by the *GainThreshold* and *LossThreshold*, described above.

$$EntityGain \; = \min\{TotalGain, GainThreshold\} \times QualityTarget$$
$$EntityLoss \; = \min\{TotalLoss, LossThreshold\}$$

We model the entity's quality performance by *QualityTarget* ϵ *(0,1),* which captures the probability that the entity will satisfy the quality target and qualify for shared savings with the payer. Thus, the entity payment is

$$EntityPayment = N \times EpisodePrice + \; EntityGain - EntityLoss.$$

Note that entity's payment corresponds to the financial margin.

II. Payer: the payer pays the episode price per patient, the outlier cost, and any losses beyond the *LossThreshold (TotalLoss—EntityLoss)* and obtain gains beyond *GainThreshold (TotalGain—EntityGain)* . Thus, the payer payment is defined as

$$PayerPayment \; = (TotalGain - EntityGain) - N \times EpisodePrice - OutlierCost - (TotalLoss - EntityLoss)$$

III. Parties within entity:

Physician payment: the physicians collect a fixed fee per patient (*PFFS*). This payment is increased or decreased depending on whether the entity achieves gains or losses and the corresponding physician's portion of the entity's shared savings (*% GainShare*) or losses (*% LossShare*). Additionally, to incentivize assumption of downside risk, the Centers for Medicare and Medicaid Services is offering a bonus to providers amounting to 5% of physician payments for those participating in qualifying advanced alternative payment models. To account for this incentive payment, we incorporate a dichotomous indicator variable *Bonus*, which results in a 5% increase in non-negative physician payments when *Bonus* = 1. We compute physician gain and loss, and the total payment as follows,

$$PhysicianGain = N \times PFFS + \%\, GainShare \times (EntityGain - N \times FFS)^{+}$$

$$PhysicianLoss = \%\, LossShare \times EntityLoss$$

$$\begin{aligned} PhysicianPayment \\ &= PhysicianGain - PhysicianLoss + 5\% \\ &\times (PhysicianGain - PhysicianLoss)^{+} \times Bonus \end{aligned}$$

Hospital payment: The hospital retains any leftover entity's profits (and incurs any residual losses) after compensating the physicians. Thus, the hospital receives,

$$HospitalPayment = EntityGain - EntityLoss - PhysicianPayment$$

Note that hospital's payment corresponds to the financial margin.

References

(1) Centers for Medicare and Medicaid Services Center for Medicare and Medicaid Innovation: Bundled Payment for Care Improvement Advanced Target Price Specifications Model Year 1 and 2 Feb 2018.

Appendix Exhibit A6: Clinical and demographic data of empirical cohort (N = 157)

	Mean (SD), N(%)
Patient	
Age	64.6 (6.8)
Prostatectomy Pathology: Gleason Score	
N/A[a]	13 (8.3%)
3+3	15 (9.6%)
3+4	82 (52.2%)
4+3	37 (23.6%)
≥4+4	10 (6.4%)
Prostatectomy Pathology: T-stage	
ypT0[b]	3 (2%)
pT2	96 (61%)
pT3	58 (37%)
Prostatectomy Pathology: N-stage	
N0	109 (69%)
N1	13 (8%
Nx	35 (22%)
Number of lymph nodes (n=122)	17.1 (9.4)
ASA physical status classification	2.3 (0.5)
Body mass index	27.3 (4.2)
Smoking status	
Never	92 (61.3%)
Former	48 (32.0%)
Current	10 (6.7%)
Income Level[c] ($)	
<50k	5 (5.4%)
50-100k	32 (32.8%)
100-200k	37 (40.2%)
>200k	19 (20.7%)
Education[d] (% change of holding a bachelor's degree based on census tract)	
<30%	18 (19.1%)
30-60%	44 (46.8%)
>60%	32 (34.0%)
Pre-operative	
Prostate MRI at institution	56 (35.7%)
Pre-operative cardiac testing at treating institution	
Electrocardiogram	38 (24.2%)
Chest radiograph	22 (14.0%)
Echocardiogram	9 (5.7%)
Stress test[e]	5 (3.2%)
Pre-operative functional recovery counseling visits	60 (38.0%)
Peri-operative	
Anesthesia operative time (min)	258.6 (49.3)
Post-operative	
Length of stay (days)	1.78 (1.51)
MS-DRG	
707 – complicated	24 (15.3%)
708 – uncomplicated	131 (84.7%)
Required escalation of care during index hospitalization	0 (0.0%)
Discharged home	157 (100.0%)
Readmitted	4 (2.5%)
Emergency department visits	13 visits by 9 (5.7%) patients
Post-operative functional recovery counseling visits	45 (28.5%)

Abbreviations: American Society of Anesthesiologists (ASA), Interquartile range (IQR), Medicare Severity Diagnosis Related Groups (MS-DRG), Standard deviation (SD)

[a]Gleason score is undefined because of morphologic changes due to neoadjuvant androgen deprivation clinical trial
[b]Complete pathologic response to neoadjuvant androgen deprivation clinical trial
[c]Missing n=64 (40.8%)
[d]Missing n=63 (40.1%)
[e]Myocardial perfusion imaging or stress echocardiogram

Appendix Exhibit A7: Details on sources of empirical financial data

	Input Variable	Data source and Description
Phase I: Pre-operative	Cost pre-operative (excluding imaging) ($)	TDABC; True internal costs to provide pre-operative clinic visits[a] and routine pre-operative testing
	Cost MRI ($)	TDABC; True internal costs to deliver a multiparametric MRI for pre-operative staging purposes
	Cost CXR ($)	TDABC; True internal costs to deliver a CXR for pre-operative clearance
	Cost EKG ($)	TDABC; True internal costs to deliver an EKG for pre-operative clearance
	Reimbursement pre-operative ($)	MFS; Reimbursement for all services, including professional and non-professional (technical) payments for all relevant CPT codes[b]
Phase II: Inpatient	% MS-DRG 707 (708)	Empirical data from 2016 cohort
	Cost of surgery and peri-operative care ($)	Hospital ABC; direct and indirect costs of supplies and services rendered in the operating room (cost of surgery) and the pre-operative holding area/post-acute care unit (peri-operative care), including personnel costs
	Personnel costs in ward ($)	TDABC; true internal costs of physician, resident, advanced care providers, nursing staff, nursing administration staff involvement in inpatient care, including direct (salary and benefits) and indirect costs
	Cost of inpatient hospitalization ($)	Hospital ABC; direct and indirect costs of medical services rendered on the inpatient ward. Individual cost centers include room and board, pharmacy, laboratory, radiology, pathology
	Reimbursement hospital ($)	MS-DRG; Inpatient Prospective Payment System reimbursement for DRG 707 or 708 with facility-specific adjustments[c]
	Reimbursement professional ($)	MFS; Reimbursement for all inpatient physician services[b,d]
	Reimbursement anesthesia ($)	Anesthesia finance department[e]
	Total LOS (non-outliers) (days) % prolonged LOS outliers Total LOS if prolonged	Empirical data from 2016 cohort
	Surgery duration (min)	Empirical data from 2016 cohort
	Time on inpatient ward (days)	Empirical data from 2016 cohort
Phase III: Post-operative	Cost post-operative ($)	TDABC; true internal costs to provide post-operative clinic visits, including surgical follow up, urology men's health visits for functional recovery counseling, and nurse visits
	Cost post-acute care[g] ($)	*Hospital ABC; direct and indirect cost of medical services rendered during emergency room visits and readmissions[f]*
	Reimbursement post-acute care[g,h] ($)	*Hospital ABC; encounter-specific reimbursement for emergency room visits and readmissions*

Abbreviations: ABC – activity-based accounting; CXR – chest x-ray, EKG – electrocardiogram, LOS – length-of-stay, MFS – Medicare fee schedules; MS-DRG – Medicare severity diagnosis related group; SD – standard deviation; TDABC – time-driven activity-based costing

[a]Includes urologic oncologist, urologic men's health specialist, primary care/anesthesia pre-operative clearance, cardiologist, radiation oncologist; Excludes multi-parametric MRI
[b]Appendix Exhibit 3
[c]Standard adjustments include wage index, cost of living, disproportionate share hospital, indirect medical education, and outlier payments
[d]Excludes anesthesia professional fees
[e]Estimated Medicare reimbursement
[f]Since TDABC estimates for professional (physician) services rendered during emergency room visits and readmissions are unavailable, they can only be estimated by professional reimbursement using Medicare Fee Schedules. While this is a standard method for estimating costs when more granular cost-accounting methods are unavailable, using reimbursement amounts to estimate costs does not contribute to an understanding of true financial margins. Therefore, professional costs and reimbursement for these unplanned encounters were excluded from the model
[g]All patients were discharged home. 9 patients with 9 emergency department visits and 4 readmissions. In our financial model, we elected not include post-acute encounters as an input variable and instead modeled cost outliers based on length of stay. Because of how infrequently post-acute care occurred, no other variable correlated with post-acute costs/reimbursements and was therefore not useful for the model.
[h]The 90-day global period negates any reimbursement for outpatient physician services rendered in the post-operative time frame

Appendix Exhibit A8: Best fit distributions for model input variables

	Input Variable	**Distribution/Formula**	**Fit** p-value [R^2]
Phase I: Pre-operative	Reimbursement outpatient ($)	Gamma (scale = 725, shape = 1.9)	0.152
	Cost pre-operative ($)	Lognornal (meanlog = 5.89, **sdlog**[a] = 0.667)	0.106
	Cost MRI ($)	= 670	-
	Probability patients receive MRI	Bernoulli (**prob** = 35.7%)	-
	Cost CXR ($)	= 20	-
	Probability patients receive CXR	Bernoulli (prob = 14%)	-
	Cost EKG ($)	= 10	-
	Probability patients receive EKG	Bernoulli (prob = 24%)	-
Phase II: Inpatient	% DRG 707 (708)	Bernoulli (prob = 15.3%)	-
	Reimbursement professional ($)	Combination of Normal(mean = 1840, sd = 74) and Gumbel (location = 2700, scale = 195). Probability of following Normal is 0.212.	0.127
	Reimbursement anesthesia ($)	Gumbel(loc= 512, scale = 53)	0.144
	Reimbursement hospital ($)	= 16000 (DRG 708) or 21000 (DRG 707)	-
	Cost of surgery and peri-operative ($)	= 858.43 + **Operating room time** * (CostMinOR = 12.07)	[1]
	Cost of personnel in wards ($)	= 62.77 + **Time in inpatient ward** * (CostMinWard = 0.733)	[1]
	Cost of inpatient hospital ($)	= 3652.8 + 2.27 * **Time in inpatient ward** +20.38 * Operating room time + ε; ε~Normal(mean = 0, sd = 1836)	[0.79]
	Total length-of-stay (non-outliers) (min)	830 * Lognormal(meanlog = 0.935, sdlog = 0.33)	0.024
	% Outliers	Bernoulli (**prob** = 3.2%)	-
	Length-of-stay outliers (min)	min[2000 * Lognorm(scale = 1.38, sdlog = 0.227); 30000]	0.158
	Operating room time (min)	Gumbel(loc = 239, scale = 30.62)	0.126
	Time in inpatient ward (min)	= Length-of-stay - **Operating room time** -141[b]	-
Phase III: Post-operative	Cost post-operative ($)	Lognorm(meanlog = 4.86, **sdlog** = 0.60)	0.028

[a]Bolded items are modifiable in the interactive application

[b]Exact time stamps for the peri-operative period are unavailable. Therefore, we estimated the pre-operative holding and post-operative acute care recovery time using time-driven activity-based costing methods (141 minutes), and assumed this to be fixed for every patient

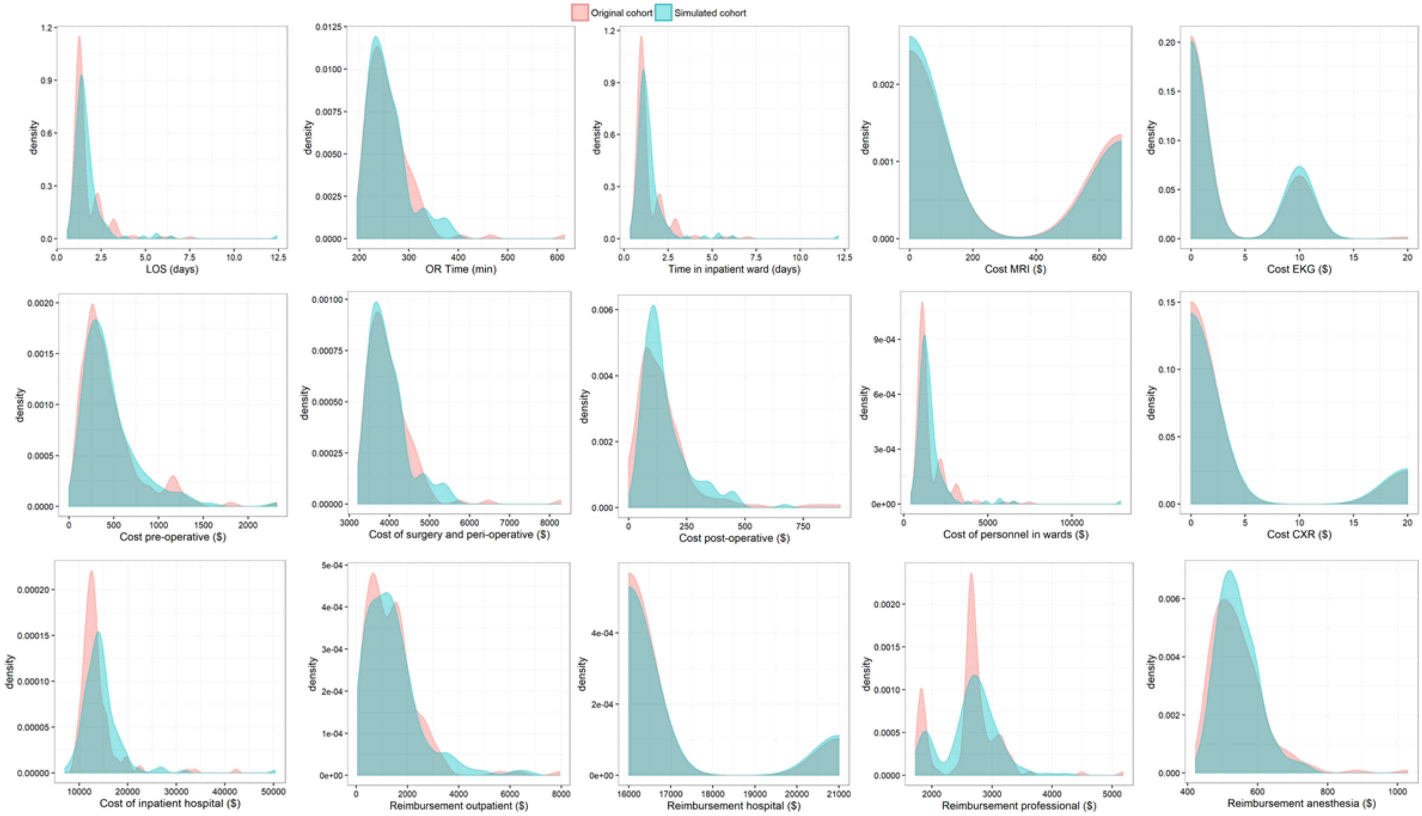
Appendix Exhibit A9: Correlogram between input variables

	LOS	OR Time	r_outpatient	r_professional	r_anesthesia	r_hospital	c_preop	c_postop	c_MRI	c_CXR	c_EKG	c_surgery	c_personnel_wards	c_inpatient_hospital
DRG	**-0.33**	-0.02	-0.17	-0.29	0.03	-1.00	0.00	-0.28	0.06	0.02	0.08	-0.02	-0.33	-0.28
LOS		**0.35**	**0.15**	**0.41**	0.11	0.33	-0.06	**0.41**	0.06	-0.14	-0.04	0.35	1.00	0.87
OR Time			0.03	0.33	0.27	0.02	0.04	0.05	-0.06	0.03	0.03	1.00	0.32	0.50
r_outpatient				0.10	0.12	0.17	0.58	0.28	0.38	0.05	0.04	0.03	0.15	0.09
r_professional					0.10	0.29	0.01	0.30	-0.02	0.10	0.08	0.33	0.40	0.39
r_anesthesia						-0.03	0.07	0.10	-0.03	-0.01	0.14	0.27	0.10	0.18
r_hospital							0.00	0.28	-0.06	-0.02	-0.08	0.02	0.34	0.28
c_preop								0.04	0.18	0.26	0.07	0.04	-0.06	-0.05
c_postop									-0.04	0.14	-0.01	0.05	0.42	0.37
c_MRI										-0.11	-0.09	-0.06	0.06	0.00
c_CXR											0.19	0.03	-0.15	-0.13
c_EKG												0.03	-0.04	-0.05
c_surgery													0.32	0.50
c_personnel_wards														0.86

To simulate new patient data, we include correlations that are relevant to the EBP model, that is, correlations between utilization variables (DRG, LOS and OR time) and costs inputs. In order to obtain FFS reimbursement simulated data that is consistent with utilization, we also include correlations between utilization variables and reimbursement components for the hospital, we did not include correlation with anesthesia reimbursement as this is a small amount relative to the other payments. Note that these correlations only impact the FFS simulated payments and do not affect the payment calculation under the EBP model.

Values in bold cells are the key correlation values included in the model (e.g., LOS is correlated with DRG).

Appendix Exhibit A10: Validation of simulated patient data. Densities of model input variables (Original empirical N = 157 and simulated N = 160 cohort data)

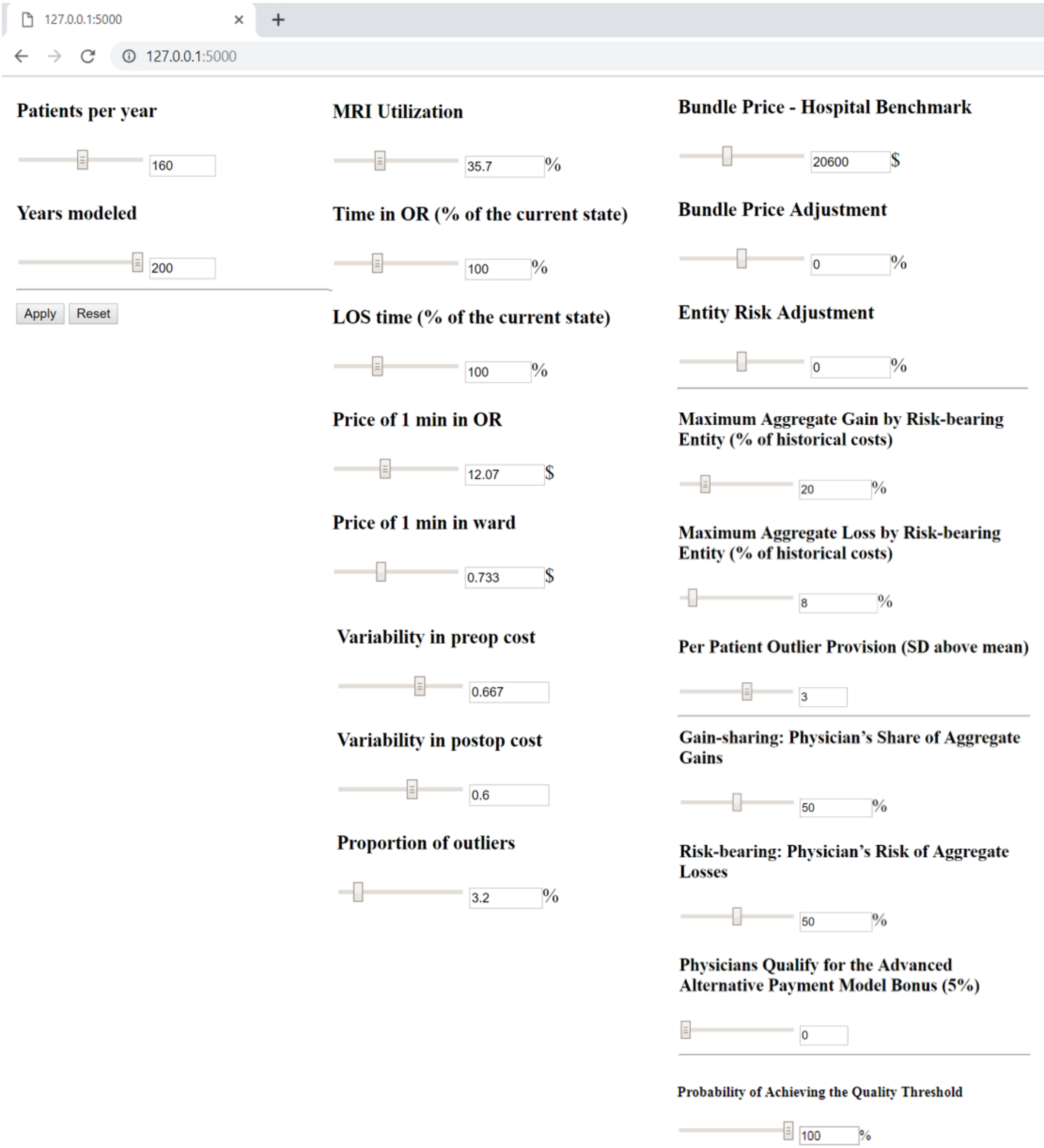


Appendix Exhibit A11: Detailed explanation of risk metrics

Formally, Value at Risk (VaR) is the quantile of the payment distribution so that the probability of observing payments below (above) that quantile is α, which is chosen a priori. For the purposes of our analysis, we consider the status quo as the specific quantile of interest (median FFS payment) and then compute the probability that EBPs are below (above) the specific quantile. Let's denote the latter probability as β. The Conditional Value at Risk (CVaR), on the other hand, measures the expected episode payment assuming that payments are below (above) the VaR. Intuitively, CVaR measures the magnitude of the payments on the tail of the distribution, representing maximum possible gains (losses) in the best- (worst-) case scenarios, which occur with a probability defined by α. In our analyses, we specifically compare the episode payment against the status quo median FFS payment for each stakeholder. Thus, we report β, i.e., the probability the episode payment model generates lower (higher) payments than median FFS, and calculate the corresponding CVaR, i.e., the average episode payment given that payment is lower (higher) than to the median FFS payment.

<u>Appendix Exhibit A12: Screenshot of user-facing web-based interface and output</u>

A. Modifiable simulation, clinical, and payment model inputs

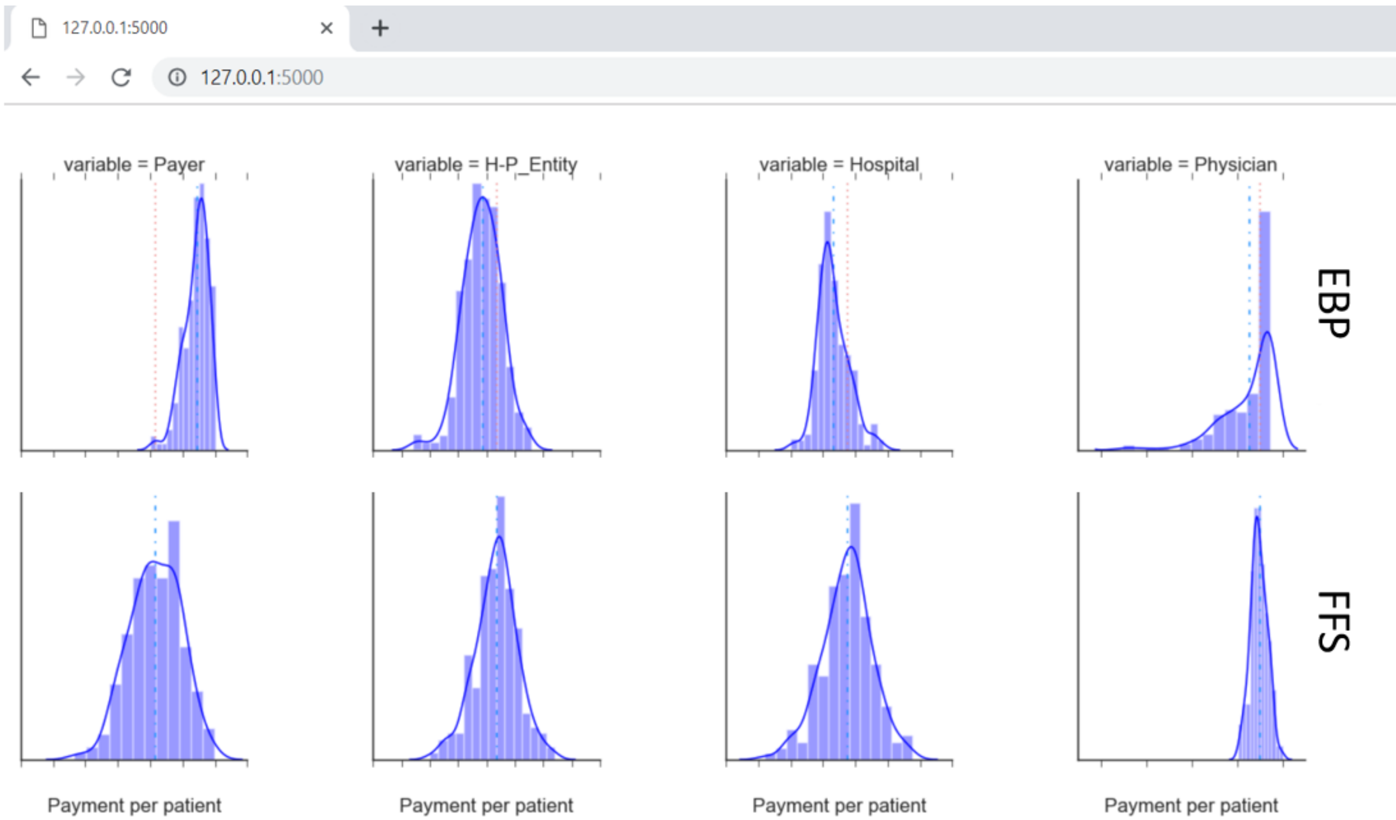


First column contains patients per year (annual case volume) and the number of simulation runs

Second column contains clinical cost drivers. These can be customized based on the specific episode of care.

Third column contains payment parameters, including episode or "bundle" price, gain-sharing/risk-bearing between stakeholders, and the quality threshold parameter

B. Graphical (distributions) and numerical (table) output of financial outcomes by stakeholder under different payment models



		Mean	SD	Var	CVar	20Q	40Q	60Q	80Q
Payer	Bundle	-20716	76	0.995	-20714	-20786	-20721	-20686	-20652
	FFS	-20969	157	0.515	-20844	-21099	-21007	-20926	-20832
H-P Entity	Bundle	-83	341	0.23	346	-347	-151	8	195
	FFS	169	377	0.535	439	-95	104	265	460
Hospital	Bundle	-2338	239	0.175	-1948	-2517	-2419	-2335	-2148
	FFS	-2128	385	0.535	-1849	-2421	-2191	-2021	-1839
Physician	Bundle	2254	119	0.525	2338	2170	2268	2344	2344
	FFS	2297	36	0.46	2328	2267	2287	2304	2328

Appendix Exhibit A13: Full financial outcomes for all stakeholders under all clinical scenarios (Exhibit 4)

Payer (payment)					
	Baseline	Decrease MRI utilization from 35.5% to 20%	Decrease OR time by 5%	Decrease variability in pre-operative costs by 50%	Decrease high cost outliers from 3.2% to 1%
Mean % change (SD) in the EBP relative to status quo FFS	1.27 (0.37)	1.29 (0.42)	1.23 (0.38)	1.18 (0.41)	1.66(0.19)
Probability that the stakeholder fares better under the EBP	0.99	0.98	1.00	1.00	1.00
Mean % change given the stakeholder fares better under the EBP compared to the status quo FFS	1.28	1.23	1.22	1.13	1.58
Mean % change given the stakeholder fares worse under the EBP compared to the status quo FFS	-0.49	-0.45	N/A	N/A	N/A
Hospital-Physician Entity (margin = payment - cost)					
	Baseline	Decrease MRI utilization from 35.5% to 20%	Decrease OR time by 5%	Decrease variability in pre-operative costs by 50%	Decrease high cost outliers from 3.2% to 1%
Mean % change (SD) in the EBP relative to status quo FFS	-93.29 (122.2)	-82.26 (124.68)	48.46 (124.90)	60.63 (123.14)	501.80 (101.42)
Probability that the stakeholder fares better under the EBP	0.23	0.26	0.64	0.71	1.00
Mean % change given the stakeholder fares better under the EBP compared to the status quo FFS	54.19	74.35	120.54	124.84	506.50
Mean % change given the stakeholder fares worse under the EBP compared to the status quo FFS	-145.56	-136.75	-81.25	-72.73	N/A
Hospital (margin = payment - cost)					
	Baseline	Decrease MRI utilization from 35.5% to 20%	Decrease OR time by 5%	Decrease variability in pre-operative costs by 50%	Decrease high cost outliers from 3.2% to 1%
Mean % change (SD) in the EBP relative to status quo FFS	-15.60 (12..55)	-14.07 (13.83)	4.10 (16.53)	5.80 (16.24)	67.12 (14.08)
Probability that the stakeholder fares better under the EBP	0.16	0.23	0.58	0.63	1.00
Mean % change given the stakeholder fares better under the EBP compared to the status quo FFS	7.46	9.17	15.79	16.78	67.76
Mean % change given the stakeholder fares worse under the EBP compared to the status quo FFS	-17.10	-17.06	-11.12	-9.26	N/A
Physician (payment)					
	Baseline	Decrease MRI utilization from 35.5% to 20%	Decrease OR time by 5%	Decrease variability in pre-operative costs by 50%	Decrease high cost outliers from 3.2% to 1%
Mean % change (SD) in the EBP relative to status quo FFS	2.26 (4.64)	2.26 (3.99)	2.26 (1.46)	2.26 (1.60)	2.26 (0.13)
Probability that the stakeholder fares better under the EBP	0.64	0.66	0.93	0.96	1.00
Mean % change given the stakeholder fares better under the EBP compared to the status quo FFS	2.07	2.05	2.22	2.21	2.27
Mean % change given the stakeholder fares worse under the EBP compared to the status quo FFS	-5.69	-4.70	-2.67	-4.40	-N/A