Fit as a Fiddle or Sick as a Dog:

Effects of Subjective Patient Reports on Uptake of Clinical Decision Support*

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Abstract: This paper reports research on improving decisions about hospital discharge – a critical healthcare quality and cost determinant identified by the Centers for Medicare and Medicaid Services. We report an experiment on effects of subjective information about patients' health status on discharge decisions as well as uptake of recommendations from a clinical decision support system (CDSS). Subjective information about readiness for discharge was obtained during examinations of standardized patients, who are regularly employed in medical education, but in our experiment had been given scripts developed for the experimental treatments. The CDSS presents evidence-based discharge recommendations obtained from econometric analysis of data from de-identified electronic health records (EHR) of hospital patients. Subjects in the experiment were third and fourth year medical students. We find that the CDSS decreases hospital stay by one day while decreasing readmissions of high-risk patients. Subjects are responding appropriately to information conveyed by standardized patients when such information is consistent with the EHR. Compared to patient discharge from the hospital absent patient reports, Eager patients when also EHR-Fit are at least seven times more likely to be discharged whereas Reluctant patients when also EHR-Sick are about four times less likely to be discharged.

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1. INTRODUCTION

In 2010, the Centers for Medicare and Medicaid Services (CMS) incurred $17.5 billion in additional hospital charges from the 19.2% of its covered patients with unplanned hospital readmission within 30 days after discharge. The rate of unplanned readmissions is a metric for low quality healthcare as well as a cost inflator. As a result, CMS has recently been penalizing hospitals with higher-than-expected readmission rates.

Hospital readmission rates could be lowered by increasing patients' hospital length of stay (LOS). But significantly increasing average LOS would limit access to care and add to the heavy burden of healthcare costs. What is needed is research on more cost-effective and quality-effective discharge criteria and tools for their application at the point of care on hospital wards.

A sketch of current discharge practice is as follows. During daily hospital rounds, the attending physician examines the patient and reviews the patient's electronic health record (EHR). How subjective information reported by patients during examinations is integrated with objective data on the patient's vital signs, lab tests results, and other EHR information to arrive at discharge decisions is unknown to the outside observer. What is clear is that almost all of the information about discharge efficacy that could be obtained from the EHR has not been applied at the point of care because of the absence of decision support tools that would make this possible.

The evidence base for a typical discharge decision – what a physician remembers from his or her own previous practice – is extremely limited in comparison to what can be learned from the big data that can be obtained from the EHR of a large hospital. A large hospital will serve many

thousands of patients per year. It will subsequently be revealed, in most cases, whether a discharge was successful or led to unplanned readmission within 30 days. The central question addressed in developing a quantitative tool – a clinical decision support system (CDSS) for hospital discharge decision making – is how to use big data from EHRs to develop a CDSS that can be applied efficaciously at the point of care.

Cox et al. (2016a) reports development of a CDSS for hospital discharge decision making and results from a laboratory experiment. Data from that experiment provide support for uptake of the CDSS. An open question is whether providers can integrate CDSS objective information with subjective information obtained from examining patients to arrive at better discharge decisions which decrease length of stay *and* readmission rate. This question is central because of two opposing problems that can occur with *any* CDSS: (1) there can be negligible uptake of the CDSS by providers; or (2) the providers can be over-reliant on the CDSS and underuse other information.

We here report an artefactual field experiment that sheds light on these two questions about our CDSS. The experiment was conducted in the Clinical Skills Objective Structured Clinical Examination (OSCE) Center of Emory University School of Medicine. OSCE staff and facilities are used as a regular part of medical school education. OSCE contracts with "standardized patients" who are actors trained to present symptoms of patients with a variety of health problems. Our experimental protocol used OSCE facilities and standardized patients to create a controlled version of the environment of a hospital patient ward. This provides vital information relevant to possible future implementation of the CDSS on hospital wards in which providers making discharge decisions would have both objective and subjective information on patient's daily health status.

Data from our experiment suggests asymmetric uptake of the CDSS recommendations with subjects revealing some resistance to adopting "Discharge Patient" recommendations while accommodating "Do Not Discharge" recommendations. We also find that there is no effect of Reluctant vs. Eager standardized patient role, *per se*, on discharge decisions. In contrast, the likelihood of a patient being discharged decreases significantly when the Reluctant behavior is consistent with EHR clinical data. Similarly, the likelihood the patient is discharged is higher when an Eager behavior is consistent with EHR clinical data. These findings are qualitatively robust with and without CDSS but magnitudes of the effects are larger in the presence of CDSS. Consequently, compared to subjects' choices in the laboratory experiment, subjects in the standardized patients experiment are prolonging the discharge in the presence of plausible Reluctant behavior and expediting the discharge in the presence of coherent Eager behavior. The overall effect of CDSS is reduced length of stay for both patient roles in the standardized patient experiment, which is consistent with CDSS effect on LOS found in the previous laboratory experiment. There is some support for the CDSS reducing readmissions for high-risk patients who underwent complex surgery procedures.

These findings suggest an interaction between information provided by the CDSS and information provided by examining patients that is explored in detail in section 4.

2. PREVIOUS RESEARCH

A foundation for this research is provided by work by our expanded team that is published in medical and economics journals. In Kassin et al. (2012) we analyzed patient data to identify risk factors for unplanned hospital readmissions. In subsequent research, we elicited physicians' stated criteria for discharge decisions (Leeds, et al. 2013), estimated predictors of physicians' actual discharge decisions (Leeds, et al. 2017), and identified clinical and demographic patient variables

that predict unplanned readmissions (Cox, et al. 2016a; Leeds, et al. 2017). Inconsistencies among physicians' stated discharge criteria, econometric estimates of their actual discharge criteria, and criteria that predict unplanned readmissions suggest that discharge decision making can be improved by application of evidence-based discharge criteria at the point of care. Our approach to providing health IT for improving discharge decision making includes development, experimental testing, and implementation of CDSS for hospital discharges.

2.1 Patient discharge estimation and prediction modeling

Out of sample performance the prediction model for readmissions was validated with standard statistical techniques demonstrating good discrimination (C statistics of 0.80) that exceeds most measures reported in prior readmission modeling studies (Kansagara, et al. 2011). When this predictive model for readmissions is compared with the clinical predictors of discharge decisions, the observed differences in the two models highlight opportunities for improving discharge decision making with CDSS (Leeds, et al. 2017). The prediction model provides the foundation of our CDSS, the output of which includes dynamically updated daily probability of readmission within 30 days of discharge for a specific patient using clinical, demographic, and census data. The model treats a patient's measured characteristics as one "patient observation" within a large sample of archived patients with similar measured characteristics but known outcomes. In this way, a current discharge decision can be informed by the aggregated experience with thousands of similar patients with known histories. Such CDSS provides a statistically informed answer to the central question: "If this patient is discharged today, what is the likelihood of unplaned readmission within 30 days?"

2.2 Laboratory experiments with the CDSS

The alpha version of our CDSS has been subjected to extensive experimental testing using residents and fourth year medical students at Emory University School of Medicine as subjects (Cox, et al. 2016a). Three experimental treatments that varied the CDSS implementations were as follows. (1) Baseline treatment: On each "experimental day," a subject views a facsimile of the de-identified patient's EHR and subsequently makes a discharge decision ("Discharge" or "Do NOT Discharge"). (2) Information treatment: On each "experimental day," a subject views the facsimile EHR, and the discharge decision recommendation and other information provided by the CDSS, and subsequently makes a discharge decision. (3) Default treatment: On each "experimental day," a subject views the same information as in the Information treatment but, importantly, the default option for the discharge decision is switched from opt-in to an opt-out of the CDSS recommendation, meaning that if the provider chooses to override the recommendation by the CDSS, he or she must enter reasons for doing so.

Data from our laboratory experiment provides support for efficacy of the CDSS in eliciting uptake of the information in the estimated model of successful discharge, most significantly in the Default treatment. This is demonstrated for the two central performance measures for hospital discharge decision making: lower readmission rate and shorter length of stay (Cox, et al. 2016a). The CDSS also supports effective discharge decision making when bundled payments are introduced in place of fee for service compensation (Cox, et al. 2016b).

In the econometric model underlying the CDSS recommendations, the patient-physician interaction is lumped into the regression error. Therefore, we designed a new experiment with standardized patients that will allow us to investigate the potential omitted variable bias, resulting from subjective information not recorded in EHR, that is present in the CDSS and the extent to

which it influences physician decision making. The precise impact of the omitted variable bias would depend on the distribution of the subjective information provided in the patient-physician interaction, which is not observable. Therefore, it is only possible to investigate this using an artefactual field experiment.

3. EXPERIMENTAL DESIGN AND PROTOCOL

We designed and conducted an artefactual field experiment using OSCE facilities and standardized patients to create a controlled version of a hospital patient ward environment. Data from this experiment provides vital information relevant to possible future implementation of the CDSS in a clinical setting in which physicians making hospital discharge decisions would have both objective and subjective information.

Subjects in the experiment were third and fourth year medical students. One-half of the subjects participated in sessions using the Baseline information from a facsimile of de-identified EHR. The other one-half of the subjects participated in sessions with the CDSS Default treatment and the EHR facsimile. All subjects also received information from examining standardized patients. Subjects in the experiment had previous experience with examining standardized patients in the OSCE patient rooms as part of their medical education.

Each standardized patient was matched with the de-identified EHR of a distinct real patient incorporated into the experiment software for the Baseline and CDSS Default treatments. A standardized patient was given instructions about the specific illness and course of treatment of the real patient they would portray. In one session, a specific standardized patient portraying a specific real patient would be instructed to present herself as eager to go home (“fit as a fiddle”). In another session, the same standardized patient portraying the same real patient would be

instructed to present herself as reluctant to go home ("sick as a dog"). For any given patient, in some but not all days during the hospital stay a "reluctant" behavior will be reinforcing information on clinical data; similarly for the "eager" behavior. An adequate uptake of the CDSS will manifest itself through discharge decisions being affected by subjective information only when not conflicting with the objective information in EHR.

The new experiment with standardized patients uses a 2 X 2 design in which the treatment cells include Information Condition (Baseline or CDSS Default) crossed with Standardized Patients (Eager or Reluctant). In addition, we have data from the earlier experiment (Cox, et al. 2016a) with Baseline or CDSS Default information conditions but without standardized patients.

We used the OSCE Center medical education facility at Emory University School of Medicine as an experimental laboratory. OSCE is conventionally used for clinical skills education, physical diagnosis, and other educational experiences. A cadre of around 100 actors, trained to portray a variety of illnesses and conditions, work at OSCE. These skilled professionals present clinical scenarios in a standardized fashion, thus earning the title of "standardized patients."

OSCE contains four suites each of which contains a central debrief room and four examination rooms equipped with a patient bed, examination table, and standard clinic equipment. Two suites were used in the experiment. In each session there were eight standardized patients to be considered for discharge. Subjects rotated through the eight examination rooms seeing one standardized patient in each room on each experimental day pre-discharge. Subjects' order in the rotation schedule was randomly determined. A subject would first review the de-identified EHR for a virtual patient up to the current experimental day using a laptop computer in the debrief room. After reviewing information on their laptop, a subject would enter the examination room to interview and examine the standardized patient paired with the virtual patient in the HER record.

After examining the standardized patient, the subject would return to the debrief room and enter her decision in the laptop of whether to discharge the patient on that experimental day. After discharging a patient the subject would continue with the rotation of the other patients. A subject was paid $15 for each successfully discharged patient. The probability a discharge would be unsuccessful was determined by the algorithm reported in Cox, et al. (2016a).

Data from the 2 X 2 field experiment reported herein is also compared to data from the laboratory experiment reported in Cox et al. (2016a) for the same virtual patients. Since the EHR data for the eight patients used in the OSCE field experiment were also used in the laboratory experiment, comparison of discharge decision responses for these eight patients between the two experiments provides additional insight into the effects of subjective information on quality of discharges and the uptake of evidence-based discharge criteria in the CDSS.

3.1 Baseline and CDSS Default Treatments

The facsimiles of EHRs used in the Baseline condition show de-identified information on real hospital patients, just as it appears on hospital wards, only with patient real names and addresses removed. Examples of such screens are contained in the appendix of Cox, et al. (2016a). In the Baseline treatment, the default option is that the patient remains in the hospital unless the physician (i.e. the subject) initiates discharge; this is the standard default option in current medical practice.

In the CDSS Default treatment, subjects get information from the CDSS as well as facsimiles of EHRs. The default option in this treatment is the recommendation of the CDSS. There are three possible recommendations from the CDSS. Figure 1 shows an example in which the CDSS recommendation is “Do Not Discharge Patient”, as shown at the bottom left of the screen. Estimated daily probabilities of readmission if the patient were to be discharged on any experiment day up to the present decision day (in this instance, day 4) are also shown on the left

side of the screen. The vertical dashed lines show 80% confidence intervals for the point estimates of readmission probabilities shown by the dots at kinks in the piecewise linear curve of estimated readmission probabilities.[1] The red horizontal line reports the *target* readmission probability for all patients with this patient's diagnosis code, which is a 10 percent reduction from the recent historical rate.[2] For the patient on this day (which is day 4), the point estimate of readmission probability is above the target rate, hence the recommended decision is "Do Not Discharge Patient"

<Figure 1 about here>

<Figure 2 about here>

The subject can accept this recommended decision by clicking on the similarly-labeled button. Alternatively, the subject can click on the button labeled Overrule and Enter Reasons and then proceed to the screen shown in Figure 2 to enter reasons for overruling the CDSS recommendation.

On experimental days for which the target readmission probability is between the point estimate and the upper bound of the 80% confidence interval, the CDSS "recommendation" is Physician Judgment, as shown in Figure 3. On experimental days in which the target readmission probability is above the entire 80% confidence interval, the CDSS recommends Discharge Patient, as shown in Figure 4. In such instances, the subject can click either on the button labeled Discharge Patient or on the button labeled Overrule and Enter Reasons. In the latter instance, the subject will need to enter reasons for overruling the CDSS by entering responses in a screen

[1] The 80% confidence interval was chosen because it allows the "Discharge" recommendations to be made with 90% confidence. This is because in order to recommend "Discharge" the 80% confidence interval must lie completely below the target readmission probability. In planned future applications on hospital wards, the responsible providers will be able to choose the confidence interval used by the CDSS.

[2] Target readmission probabilities can be chosen by
the responsible providers in future applications on hospital wards.

<Figure 3 about here>

<Figure 4 about here>

similar to the one in Figure 2. In screens shown in Figures 1, 3, and 4 the six charts on the right two-thirds of the screen show values of clinical variables (and their normal ranges) that are probabilistically most important for the discharge decision on the current experimental day for this specific patient. The selection of clinical variables displayed is dynamically updated on a daily basis.

3.2 Reluctant and Eager Standardized Patient Treatments

Table I shows an example of the sketch of clinical information provided to the standardized patients. The table reports a summary of some of the clinical information in the EHR of the patient known as Ashley Barnes in the experiment. It shows the patient's pseudonym, real age, and real surgical procedure. It also reports the experimental day, and real hospital stay day, pain score, pain medication, stool count, and type of diet.

<Table I about here>

Table II shows the alternative scripts given to the actor playing Ashley in the treatments in which Ashley was Reluctant or Eager to be discharged. The Reluctant and Eager treatments differ in the instructions for patient portrayal in the categories labeled appearance, pain score, activity, bowel function, diet, and social support. Note that, on days earlier than the seventh day in the hospital, reluctant behavior is consistent with the clinical data because Ashley's diet is NPO (nothing by mouth) whereas on later days reluctant behavior might simply convey a general pessimistic attitude and stop serving as an informative signal of her health status.

<Table II about here>

4. RESULTS

A total of 38 subjects participated in the standardized patient experiment. Subjects were third and fourth year medical students. They were paid $15 for each successfully discharged patient. They were not paid for discharging a patient who was readmitted. Average subject earnings in the Baseline and CDSS Default treatments were $110.53 and $112.11.[3] Experimental sessions took about 2 and one-half hours. Subject instructions used in the experiment are available online at https://excen.gsu.edu/jccox/docs/FitAsaFiddle.pdf.

In some of our data analysis we compare results in the standardized patient experiment reported herein with data from the laboratory experiment with (the same eight) virtual patients reported in Cox, et al. (2016a). The laboratory experiment used 47 subjects. A detailed discussion of the demographics of the subjects used in both experiments is contained in an appendix available from the authors.[4]

4.1 Hospital Length of Stay

A patient's length of stay (LOS) is central to the cost of providing health care. One objective of the CDSS is to lower these costs by lowering a patient's LOS while simultaneously not increasing their probability of readmission. The objective function programed into the CDSS is minimization of hospital length stay subject to a quality constraint: the readmission rate be no higher than 90%

[3] The maximum amount of earnings is $120 (=8*$15). The lower figures on average earnings reveal that some of the discharged patients were readmitted and therefore subjects were not paid for them.

[4] We use subject demographic variables such as academic performance, risk attitudes, gender and experience as a musician or competitive athlete in our data analysis. Musical and athletic subject identifications are used because they are selection criteria in medical school admission decisions.

of the recent average recorded readmission rate for the surgical procedure category the patient is undergoing.[5] Table III contains OLS estimates[6] of treatments for patients' LOS.

<Table III about here>

Data from the standardized patient experiment indicate that CDSS Default lowers LOS by approximately one day. Reduction in LOS accompanied by *no* increase in the readmission rate (as reported in the following section) suggests that CDSS Default meets the double objectives of lowering costs without jeopardizing the quality of discharge decision making. This is consistent with the findings of Cox et al. (2016a). The standardized patient treatments have a substantial impact on the patient LOS. If a standardized patient indicates that he is reluctant to leave the hospital then his discharge is prolonged by approximately two days relative to a patient appearing Eager to leave the hospital. Therefore, subjects pay considerable attention to the subjective information provided by patients. In section 4.4 we explore the direction and timing of the subjective information attracting the attention of subjects. Other factors associated with longer LOS include indicators of slow post-surgery recovery such as: (i) patient start date, i.e. how long the patient has been in the hospital until the first day the subject visits him, and (ii) the patient undergoing complex surgical procedures, the ones with historical readmission rates exceeding 17%.

[5] This 10% reduction from historical readmission rates was selected because it was a stated goal by the Centers for Medicare and Medicaid Services. In planned future implementations on hospital wards, the responsible providers will be able to choose the readmission rate objectives in applications of the CDSS.
[6] Tobit regression estimates are similar to OLS estimates.

4.2 Quality of Discharge Decisions: Readmission Rates

The effectiveness of the CDSS hinges on its ability to generate efficient discharge decisions. Discharging a patient earlier is not desirable if it results in a higher readmission rate. Table IV reports the Odds Ratio derived from the logistic regression estimates; in addition to treatment variables the list of regressors includes additional variables that are relevant to the likelihood of readmission, such as log of the hospital stay (Ln(LOS)).

<Table IV about here>

We find that in the standardized patient experiment, the CDSS Default significantly decreased probability of unplanned readmissions for High Risk patients. In the CDSS Default treatment High Risk patients are about 4.5 times less likely to be readmitted. The role of the standardized patient has no significant effect on readmissions. Other findings include: (i) High Risk patients are three times more likely to be readmitted; and (ii) longer hospital stay is associated with lower readmission risk. None of the other variables of interest have a statistically significant impact on readmission rates, including whether a standardized patient's behavior is Reluctant or Eager. Data from the laboratory experiment point to similar factor effects with the exception of the CDSS treatment effect on reducing readmissions for High Risk patients losing its statistical significance.

4.3. Concordance with CDSS Recommendations

Concordance is defined as choosing to discharge (resp. not discharge) the patient when the CDSS Default recommendation is Discharge (resp. Do not Discharge). Given that it is not possible to measure concordance when the CDSS does not make a recommendation (i.e., "physician judgment"), we remove these data points from this segment of the analysis. The average CDSS

treatment effect on subjects' decisions is measured as the difference between the level of concordance across the CDSS Default and Baseline treatments.

One of our main hypotheses is that the subjective information provided by the standardized patients will affect the subjects' willingness to follow the CDSS. The average overall concordance rate in the laboratory experiment was approximately 78% in CDSS Default and 63% in Baseline, suggesting a CDSS treatment effect on concordance of 15%. In the experiment with standardized patients, the concordance rates are expected to be affected by the consistency of the subjective behavior and objective clinical EHR data but the total effects are expected to be smaller if subjects are not over-relying on the CDSS. We find that the average concordance rates in the standardized patient experiment are indeed smaller: 63% (CDSS Default) and 59% (Baseline), suggesting a CDSS treatment effect on concordance of about 4%. Table V further breaks down the concordance rates by experimental treatment, type of patient behavior and discharge CDSS recommendation. Across both the standardized patient and laboratory experiments the concordance rate is significantly lower when the CDSS recommends discharge, which reveals subjects' preferences for being cautious and delaying discharge especially for standardized patients portraying reluctant behavior.

When the CDSS recommends "Discharge" the concordance rate is 0.38 for Reluctant and increases to 0.58 for Eager standardized patients. With the "Do not Discharge" recommendation, the concordance rate is 1 for Reluctant but decreases to 0.89 for Eager standardized patients

Taking into account the concordance rate figures in the Baseline, the CDSS treatment effect on concordance rates when the recommendation is Discharge is approximately 13% (t=2.48, p-value=0.012, N=38) for Reluctant and 7% (t=0.83, p-value=0.410, N=38) for Eager standardized patients experiment. It is twice as much (27%; t=4.70, p-value=0.000, N=46) in the

laboratory experiment. This indicates that subjects paid considerable attention to the subjective information provided by the standardized patients. When the recommendation is "Do not Discharge" our data suggest no CDSS effect.

<Table V about here>

4.4 Effects of CDSS, EHR and Patient subjective reports on Discharge Decisions

A standardized patient conveyed either a reluctance or eagerness to be discharged, regardless of the CDSS default recommendation. It is of vital importance for an effective implementation of the CDSS that physicians assisted by this analytical tool do not ignore other pieces of information about the recovery status of the patient including subjective information provided by patients. On the other hand, such subjective information rather than being an informative signal of the state of the patient's recovery might simply reflect a patient's general level of tolerance towards pain or unpleasantness of being in the hospital.

The ambiguity of the relevance of the subjective message delivered by the patient on the readiness of the patient for discharge calls for investigating the impact of these signals on the care provider's decision whether to discharge the patient, despite the availability of a CDSS recommendation. In our experimental design, for any given patient, there are days in hospital during which a signal sent by a Reluctant patient is consistent with the information in EHR. By design, there are also days during which Eager behavior reinforces information in the EHR that the patient is ready to be discharged. Our design allows for discrimination between the effect of informative and non-informative signals of readiness to be discharged conveyed by Reluctant or Eager behavior. Our hypotheses on the effect of patient behavior on discharge decisions are as follows.

1. Reluctant Behavior: The likelihood of discharging a patient absent subjective reports is higher than likelihood of discharging a Reluctant patient whose behavior is consistent with EHR clinical data.
2. Eager Behavior: The likelihood of discharging a patient absent subjective reports is lower than likelihood of discharging an Eager patient whose behavior is consistent with EHR clinical data.

< Table VI about here>

Data are consistent with both hypotheses. A Reluctant patient whose behavior is consistent with the EHR data is about 4.2 times less likely to be discharged than in the absence of patient subjective reports. Furthermore, an Eager patient whose behavior reinforces the information in EHR is between seven (absent CDSS) and fifteen (CDSS) times more likely to be discharged than in the absence of patient subjective reports.

5. CONCLUSION

One-half of the subjects in the experiment participated in sessions using the Baseline information from a facsimile of de-identified EHRs. The other one-half of the subjects participated in sessions with the CDSS Default treatment and the EHR facsimile. All subjects also received information from examining standardized patients. Subjects in the experiment had previous experience with examining standardized patients in the OSCE patient rooms as part of their medical education.

Each of the standardized patients was given instructions for portraying an individual hospital patient with a specific illness and course of treatment. In addition, one-half of the standardized patients in each session were given instructions to report feeling well and being eager to go home; these are referred to as Eager patients. The other one-half were given instructions to report feeling badly and being reluctant to be discharged; these are referred to as Reluctant patients.

In a second, paired session the role of a specific standardized patient was reversed between Eager and Reluctant. Each subject encountered both Eager and Reluctant standardized patients in each session.

Results from the standardized patient experiment support efficacy of the CDSS. However, that efficacy is significantly decreased by the subjective reports of Reluctant patients when such information is consistent with clinical data in the EHR. Reluctant reports increase LOS by over two days and reduce uptake of the CDSS recommendation "to discharge" a patient by about 20%. The subjective information provided by the patient has a significant impact on discharge decision making when such behavior is consistent with the recovery state of the patient as indicated by EHR.

The next step in testing the CDSS will come from a field experiment in the form of an intervention on patient wards. Before that is possible, we must develop a beta version of the CDSS that can interact with EHRs in real time. Recent advances in health IT such as Fast Healthcare Interoperability Resources (FHIR) and Substitutable Medical Applications and Reusable Technologies (SMART) enable innovators to seamlessly link CDSS applications to EHRs. We are developing a prototype SMART on FHIR application of our CDSS intended to be used at the point of care on hospital wards.

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FIGURES

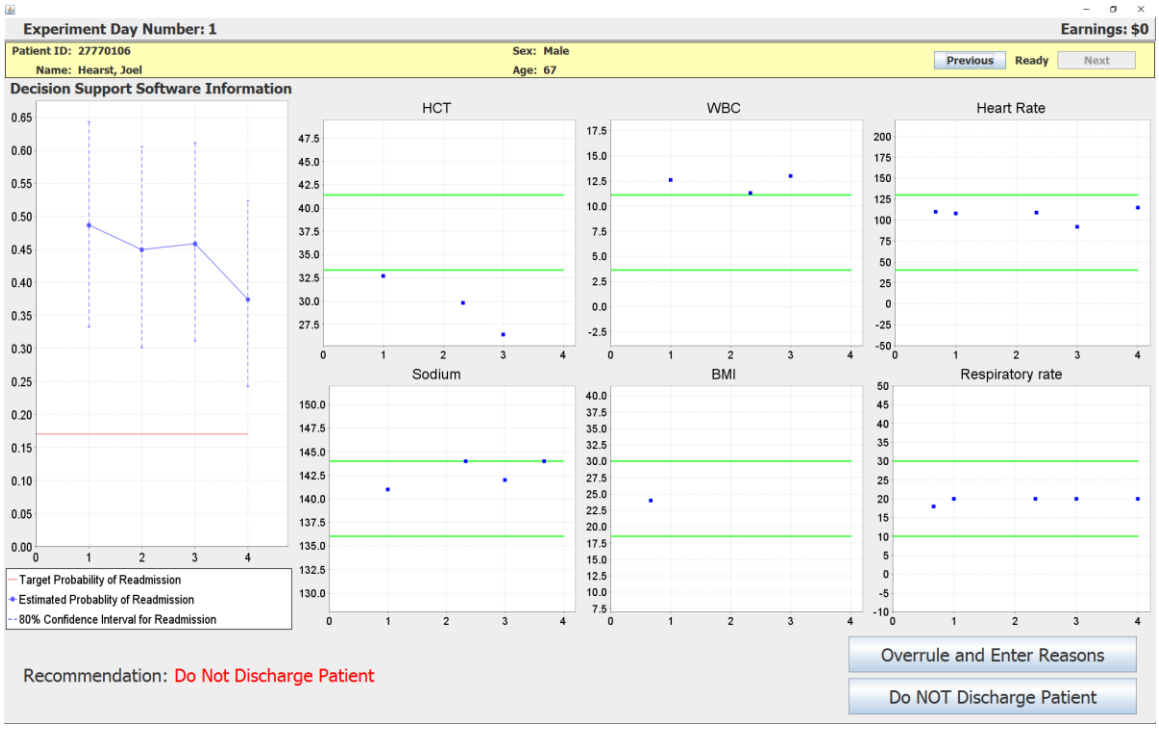

Figure 1. CDSS Default Treatment Decision Screen with Negative Recommendation

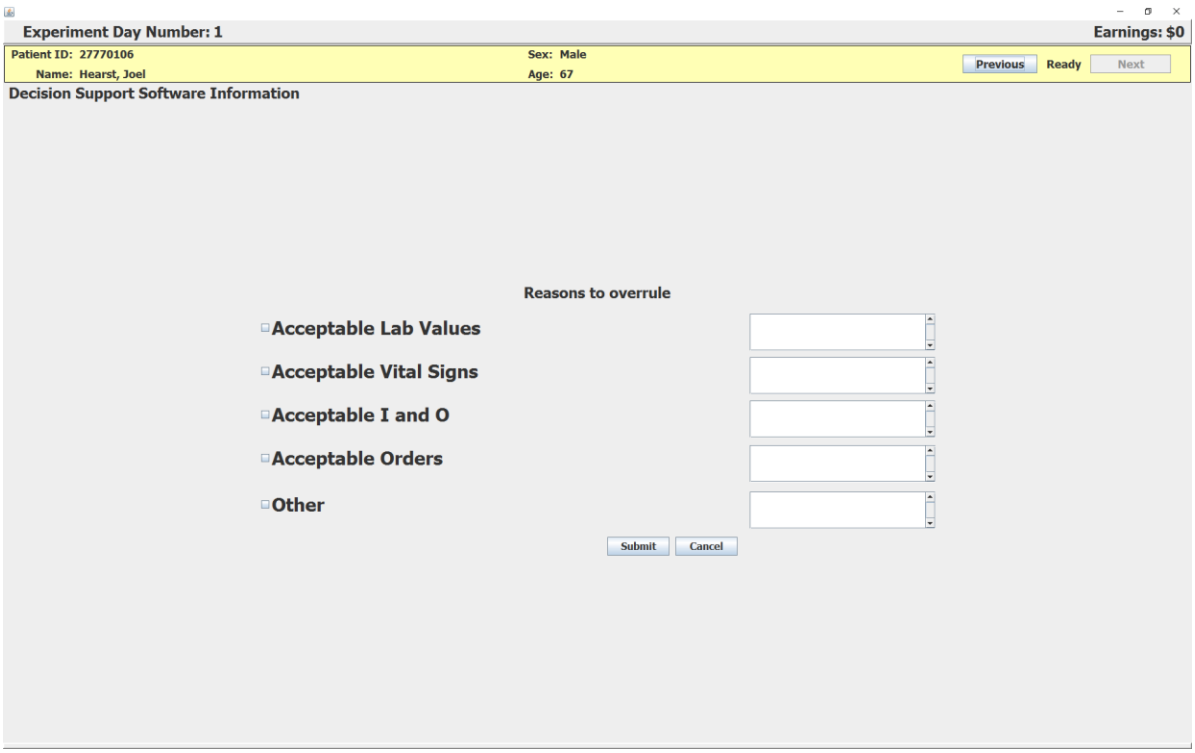

Figure 2. Reasons to Overrule a Negative Recommendation

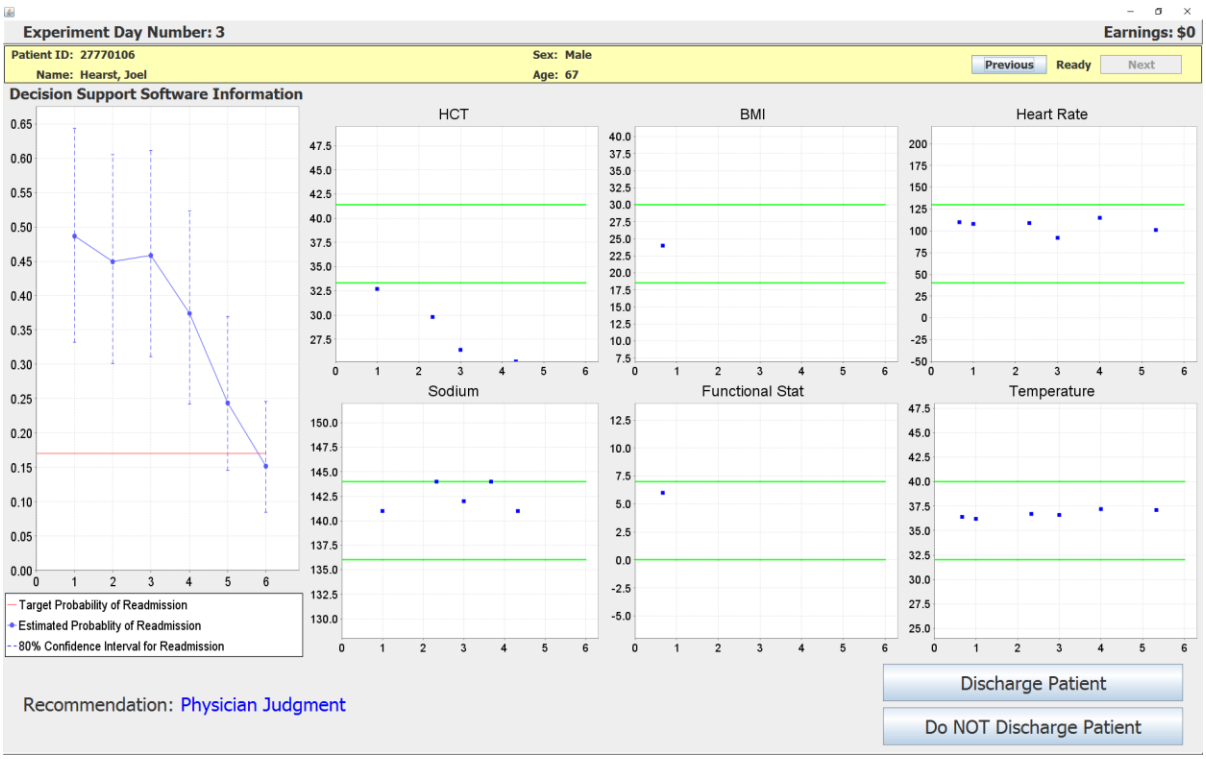

Figure 3. CDSS Default Treatment Decision Screen with Physician Judgment "Recommendation"

Figure 4. CDSS Default Treatment Decision Screen with Positive Recommendation

TABLES

TABLE I

EXAMPLE OF PATIENT CLINICAL INFORMATION GIVEN TO STANDARDIZED PATIENTS

27780512 Barnes, Ashley COLECTOMY +/- COLOSTOMY

This is a 28 year old female with a history of Peutz-Jegher's syndrome that underwent a left colectomy for treatment of a colon mass. She is now %d-days post op.

Experiment Day	1	2	3	4	5	6	7	8	9
Hospital Day	1	2	3	4	5	6	7	8	9
Pain Score	0	0	5	0	3	4	6	0	0
Pain Med								PO	
Stool Count								2	
Diet	NPO	NPO/Solids	Solids	NPO	NPO	NPO	NPO/Clear	Clear/Solids	Solids

TABLE II

SCRIPTS FOR RELUCTANT AND EAGER FOR DISCHARGE GIVEN TO STANDARDIZED PATIENTS

	Reluctant to go home	**Eager to go home**
Appearance	Looks disheveled and uncomfortable	Looks well and is asking to leave as soon as MD thinks it's OK
Pain Score	Pain is minimally covered with current pain meds	Pain is tolerable and meds help control the discomfort
Activity	Having difficulty getting out of bed alone and has trouble walking in the hallways	Up and walking in the hallway; no problem getting out of bed
Bowel Function	Is having bowel function but still feels bloated and uncomfortable	Passing gas and moving bowels normally no problem there
Diet	Not interested in any of the food that is brought to them and overall no appetite; has nausea when eats	Tolerating food and has good appetite
Social Support	No one to pick the patient up until much later in the day; worried that he/she will be alone much of the day and therefore may have some problems	Plenty of home support; could leave right now if provider wants to send the patient home

TABLE III
LENGTH OF HOSPITAL STAY

Standardized Patients	**Present**		**Absent**	
	(1)	(2)	(3)	(4)
Constant	3.692***	3.349	5.672***	6.963**
	(0.437)	(2.882)	(0.304)	(2.964)
Start Date	0.651***	0.651***	0.336***	0.336***
	(0.058)	(0.058)	(0.044)	(0.044)
High Risk (D)	0.820**	0.809**	1.226***	1.217***
	(0.327)	(0.336)	(0.351)	(0.361)
Treatments				
CDSS (D)	-0.965**	-1.197***	-1.296***	-1.187***
	(0.377)	(0.421)	(0.390)	(0.369)
CDSS x High Risk (D)	0.303	0.315	0.220	0.252
	(0.326)	(0.337)	(0.390)	(0.405)
Reluctant (D)	2.097***	2.104***		
	(0.284)	(0.288)		
Demographics	no	yes	no	yes
Observations	306	306	402	402
Nr. of clusters	38	38	47	47
R^2	0.588	0.596	0.265	0.282

Notes. Dependent variable: Total number of days the patient stayed in the hospital until being discharged. All columns report OLS estimates. Parentheses contain robust standard errors clustered at the subject level. Data from the standardized patient experiment are used in the first two columns whereas the third and fourth columns correspond to data from the laboratory experiment. Demographic variables are: Undergrad GPA, Medical School GPA, Female, Musical training, Athletic training, Risk Attitudes. Statistical significance level: *** p<0.01, ** p<0.05, * p<0.1.

TABLE IV

QUALITY OF DISCHARGE DECISIONS

Standardized Patients	Present		Absent	
	(1)	(2)	(3)	(4)
Ln(LOS)	0.062***	0.065***	0.158***	0.134***
	(0.046)	(0.048)	(0.075)	(0.070)
High Risk (D)	3.265**	3.246**	5.584**	5.971**
	(1.582)	(1.661)	(3.894)	(4.308)
Treatments				
CDSS (D)	1.099	1.040	1.703	2.018
	(0.615)	(0.561)	(1.032)	(1.252)
High Risk x CDSS (D)	0.218*	0.212*	0.338	0.333
	(0.198)	(0.200)	(0.253)	(0.247)
Reluctant (D)	1.030	1.058		
	(0.524)	(0.603)		
Demographics	no	yes	no	yes
Observations	306	306	381	381
Nr. of clusters	38	38	47	47
Pseudo R^2	0.130	0.169	0.072	0.108

Notes. Dependent variable: An indicator variable that takes value 1 if the patient is readmitted. All columns report Odds Ratios derived from Logit estimates. Parentheses contain robust standard errors clustered at the subject level. Data from the standardized patient experiment are used in the first two columns whereas the third and fourth columns correspond to data from the laboratory experiment. Demographic variables are: Undergrad GPA, Medical School GPA, Female, Musical training, Athletic training, Risk Attitudes. Statistical significance level: *** p<0.01, ** p<0.05, * p<0.1.

TABLE V
CONSISTENCY WITH THE CDSS RECOMMENDATIONS

Standardized Patients		**Present**		**Absent**
Treatment	Recommendation	Reluctant	Eager	
CDSS	"Discharge"	0.38	0.58	0.60
	"Do not Discharge"	1.00	0.89	0.94
Baseline	"Discharge"	0.25	0.51	0.33
	"Do not Discharge"	1.00	1.00	0.92
CDSS Effect	"Discharge"	0.13**	0.07	0.27***
	"Do not Discharge"	0.00	-0.11	0.02

Notes. Table reports averages of mean consistency rates across subjects. Consistency variable takes value 1 if subject's discharge decision is the same as the CDSS recommendation; discharge decisions on days for which CDSS makes no recommendation are not included. For each subject, we created the mean consistency rate for each recommendation (Discharge, Do not Discharge) and for each patient type. Data from the standardized patient experiment are used in the first two columns whereas the third column uses data from the laboratory experiment. Statistical significance level for t-test: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

TABLE VI

PATIENT BEHAVIOR EFFECTS ON DISCHARGE DECISIONS

Patient Behavior	**Reluctant or Absent**			**Eager or Absent**	
Treatment	**CDSS**	**no CDSS**		**CDSS**	**no CDSS**
Reluctant (D)	0.899	1.002	Eager (D)	0.777	0.887
	(0.280)	(0.251)		(0.214)	(0.306)
Reluctant x Sick (D)	0.218***	0.239***	Eager x Fit (D)	15.156***	7.495***
	(0.073)	(0.069)		(7.473)	(2.415)
Hospital Day Dummies	yes	yes		yes	yes
Demographics	yes	yes		yes	yes
Observations	1,071	1,475		933	1,291
Pseudo R^2	0.128	0.149		0.167	0.158

Notes. Dependent variable: An indicator variable that takes value 1 if the patient is discharged from the hospital. All columns report Odds Ratios derived from Logit estimates. Parentheses contain robust standard errors clustered at the subject level. Data from the laboratory experiment and from the standardized Reluctant patient experiment are used in the first two columns whereas the third and fourth columns correspond to data from the laboratory experiment and the standardized Eager patient experiment. Separate indicator variables for each day in hospital are included in all columns. Demographic variables are: Undergrad GPA, Medical School GPA, Female, Musical training, Athletic training, Risk Attitudes. Statistical significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.