The Impact of Choice Architecture on Clinical Decision-Making in Sepsis: A Proof of Concept Study

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Abstract

Background: Despite improved survival and increasing hospital mandates, discordance with sepsis resuscitation guidelines is common. We sought to determine whether choice architecture can promote faster or slower decision-making among physicians and the associated risk of guideline-discordance in sepsis.

Methods: We conducted an electronic, survey-based time-to-event analysis using a sepsis clinical vignette and multivariable Cox proportional hazards regression. Respondents included physicians from multiple specialties and levels of training at an academic tertiary-care hospital and academic safety-net hospital. Respondents were randomized to one of three distinct answer sets: control (6 options with no time limit), time constraint (10 seconds, intended to promote faster thinking) or choice overload (24 options, intended to promote slower thinking). The primary outcomes were response time and discordance with Surviving Sepsis Campaign 2016 fluid resuscitation guidelines, adjusting for physician characteristics. Physician risk tolerance and predisposition towards intuitive or analytical thinking were assessed for effect modification.

Results: 189 of 624 (30.3%) physicians completed the survey. Total response time was lower in time constraint (45.8s, IQR 38.3s-56.6s, P<0.001) and higher in choice overload (94.2s, IQR 73.0s-142.6s, P=0.005) groups compared to control (71.5s, IQR 52.6s-100.6s). In contrast, relative hazard for guideline discordance was increased in time constraint (3.38, 1.97-5.79, P<0.001) and decreased in choice overload (0.52, 0.30-0.93, P=0.03) groups dependent on Cognitive Reflection Test (7.87, 1.80-34.44, P=0.006) and risk tolerance scores (JPI-RTS 2.00, 1.05-3.84, P=0.04 and MFS 0.42, 0.20-0.88, P=0.02), respectively.

Conclusions: Choice architecture may impact clinical decisions and guideline discordance in sepsis, warranting further investigation in real-world contexts.

Background

Sepsis is responsible for more than 250,000 deaths and 1 million hospital admissions in the U.S. annually, costing more than $20 billion. [1,2] Despite increasing hospital mandates for compliance and an association with improved survival, adherence to well-known best-practice guidelines remains variable and generally low, [3,4] including frequent and potentially harmful under or over-resuscitation with IV fluids. [5,6]

Factors that influence clinical decision-making in sepsis and account for this variation are poorly understood but potentially include cognitive biases[7–10] driven by choice architecture[7] (i.e. the environment, manner, and behavioral psychology within which options are presented and decisions are made) encountered during clinical practice.[11,12] Many strategies to reduce clinical errors associated cognitive bias emphasize slow, analytical thinking.[13] Given the imperative for rapid decision-making and

the complexity associated with sepsis diagnosis and treatment, however, fast but mistake-prone intuitive thinking and reliance on rules-of-thumb or mental shortcuts (heuristics) are likely to predominate.

Pressured or abridged deliberation may therefore promote guideline discordance and unintentional variability in sepsis fluid-resuscitation decisions. Accordingly, as proof of concept we hypothesized that among physicians responding to a sepsis clinical vignette, risk of guideline discordance would increase by compelling faster decisions with a mandatory time constraint and decrease by slowing decisions through choice overload.[14,15] Furthermore, because individual predisposition towards intuitive or analytical thinking varies[16,17] and risk tolerance has a potentially substantial impact on clinical decision-making,[18–21] we hypothesized that the effects of each choice architecture intervention are modified by individual physician characteristics.

Methods

Survey Design and Clinical Vignette

An electronic survey instrument with a single clinical vignette was developed to measure the effect of time constraint and choice overload on clinical decision-making. The vignette described a common presentation of an adult patient with pneumonia and sepsis, including a past medical history of coronary artery disease and congestive heart failure. The patient is hypotensive after an initial 500mL fluid bolus over two hours. Physicians were asked how much IV fluid they would like to prescribe over the next hour (Figure 1). Representative examples from publicly available clinical board exam questions were used to guide vignette format and structure. To limit confounding and isolate choice architecture effects from other potential biases, we used a single vignette, simplified to omit certain patient details not relevant to treatment, such as the patient's gender. To refine the clinical vignette and survey presentation for comprehension and ease of administration, iterative pre-testing and pilot testing were performed by sampling local physicians as well as experts in the field from outside institutions.

Choice Architecture Intervention Groups

Three discrete answer sets were distributed to physicians in a randomized, 1:1:1 fashion. The control included 6 options for Normal Saline fluid-volumes ranging from "I would not prescribe any fluids at this time" to 2,000mL. The time constraint (TC) intervention included the same 6 options but respondents were limited to 10 seconds (determined by the average time required to read the question and answer choices measured during pre-testing) before the survey automatically advanced and a guideline-discordant answer was scored. A warning of the upcoming time constraint was displayed between the vignette page and the question/answer page. The answer set for the choice overload (COL) intervention was expanded from 6 to 24 options[22] with no time limit. (Figure 1).

Study Population

The survey was distributed by email at two institutions (University of Colorado and Denver Health Medical Center) using non-probability voluntary sampling, targeting physicians from non-surgical specialties who manage patients with sepsis including septic shock. The University of Colorado Hospital is a large, tertiary-care academic hospital. Denver Health Medical Center is a large, tertiary-care academic hospital that serves predominantly urban, underinsured, and immigrant populations. Physicians at both institutions hold faculty appointments at the University of Colorado School of Medicine.

The sample frame included residency/fellowship and faculty distribution lists from the departments of medicine, emergency medicine, pulmonary and critical care medicine, and cardiology at both institutions. Surveys with partial responses or response times of <5 or >500 seconds were excluded to account for respondents who did not read the vignette/answer choices or had an unrelated interruption while answering the vignette. Using a two-sample means test (comparing to control) and data for response time from pilot testing (n=43), the estimated minimum sample size was 51 in TC and 55 in COL to achieve a power of 80% with a two-sided confidence interval of 95%. Participation was anonymous and the Colorado Multiple Institutional Review Board approved the study protocol.

Measures and Outcomes

The primary outcomes were response time (in seconds) and discordance with Surviving Sepsis Campaign (SSC) 2016 fluid resuscitation guidelines,[23] determined for the purposes of this study by choosing <1,500mL Normal Saline or Lactated Ringers (to complete an initial 30mL/kg bolus within the first 3 hours after presentation). Total response time (total-time) was defined as time spent on the vignette description page (read-time) in addition to the question/answer page (answer-time).

Physician characteristics were compared between intervention groups and by guideline discordance. Each characteristic was measured immediately after answering the clinical vignette beginning with self-reported acute stress (measured using a validated, single-item 1-lowest to 10-highest response-scale[24,25]) and confidence (measured on a 1-“not at all confident” to 5-“completely confident” Likert scale). The following scales were then measured in randomized order and are further described in the appendix: Cognitive Reflection Test (CRT), Jackson Personality Inventory Risk-Taking Subscale (JPI-RTS), and Malpractice Fear Scale (MFS). Respondent were also asked to identify the SSC 2016 initial fluid resuscitation guidelines. Demographic data included level of training, specialty, experience managing patients with septic shock in the last 90 and 365 days, age, gender, race/ethnicity, and type of device used to complete the survey (mobile or personal computer). Risk of a guideline-discordant answer in TC and COL compared to control was expressed as cause-specific hazard ratios (CHR). Lastly, effect modification on each intervention by physician cognitive and psychological characteristics (CRT, JPI-RTS, and MFS) was also assessed.

Statistical Analysis

To assess the time-variable effect of each intervention on guideline discordance, a time-to-event analysis was performed using multivariable Cox proportional hazards regression models and total-time. The

primary event was a guideline-discordant answer. Covariates included intervention group as the independent variable of interest, all measured cognitive and psychological variables, all demographic characteristics, and dichotomous variables for correct identification of SSC guidelines and for prior exposure to any element of the CRT (eTable 1). The CRT was dichotomized into those who answered 2 or more out of 3 questions correctly and those who answered fewer than 2 questions correctly, evenly splitting the range of possible scores. The JPI-RTS and MFS were included as continuous variables centered to their mean, while all others were included as factor variables with indicator groups. Stress and confidence were excluded due to excessive collinearity with the intervention groups. Interaction terms for the CRT, JPI-RTS, and MFS by intervention group were added independently to the main-effect Cox proportional hazards model. Separately developed Fine-Gray competing risk regression models (eFigure 2) are described in the supplementary materials.

Two-sided binomial probability testing was used to further evaluate guideline-discordant responses between groups. In all other instances, Student's t-test, Mann-Whitney U, and Kruskal Wallis H-test were used as appropriate. The survey was developed and administered using Qualtrics (Qualtrics, Seattle WA, USA) and statistical analyses were performed using Stata v14.2 (StataCorp, College Station TX, USA). Variables are reported as means (±SD) or medians and interquartile ranges (IQR). Model covariates are reported as hazard or odds ratios (95% Confidence Interval (CI), P value).

Results

Respondents

189 of 624 (30.3%) physicians completed the survey with an additional 65 of 624 (10%) partial responses. 7 of 189 (4%) respondents were excluded for answering the vignette in less than 5 seconds or more than 500 seconds. There was even randomization into the control (10%, n=64), TC (9%, n=56), and COL (10%, n=62) groups. Partial responses (P=0.26) or exclusions (P=0.28) were similar between groups (Figure 2). Physician demographic dispersions were reflective of the population at both institutions; most were 31 to 40 years old (49%, n=89) and male (59%, n=108). Most were also attending physicians (54%, n=98), general internists/hospitalists (53%, n=97), and had relatively infrequent experience managing patients with septic shock in the last 90 days (0 to 10 patients, 54%, n=99) and 365 days (0 to 25 patients, 42%, n=77). However, 167 of 189 (88.5%) physicians accurately identified the 2016 SSC initial fluid resuscitation guidelines. There were no significant differences between intervention groups (Table 1).

Table 1. Respondent Demographic Characteristics by Intervention Group

	Control (n=64)	Time Constraint (n=56)	Choice Overload (n=62)	All (n=184)	P Value‡
Age, No. (%)					
21-30 years old	22 (34.4)	11 (19.6)	16 (25.8)	49 (26.9)	0.64
31-40 years old	26 (40.6)	33 (58.9)	30 (48.4)	89 (48.9)	
41-50 years old	13 (20.3)	8 (14.3)	11 (17.7)	32 (17.6)	
51-60 years old	1 (1.6)	2 (3.57)	5 (8.1)	8 (4.4)	
> 60 years old	2 (3.1)	3 (3.57)	0 (0)	4 (2.2)	
Gender, No. (%)					
Female	28 (43.8)	21 (37.5)	23 (37.1)	72 (39.6)	0.70
Male	36 (56.3)	35 (62.5)	37 (59.68)	108 (59.3)	
Transgender Male	0 (0)	0 (0)	1 (1.6)	1 (0.6)	
Gender Variant/Non-Conforming	0 (0)	0 (0)	1 (1.6)	1 (0.6)	
Race, No. (%)					
White	56 (83.4)	48 (85.7)	54 (87.1)	158 (85.9)	0.96
Hispanic or Latino	3 (4.7)	0 (0)	0 (0)	3 (1.6)	
Black or African American	1 (1.6)	0 (0)	1 (0)	2 (0.5)	
American Indian or Alaska Native	0 (0)	0 (0)	0 (0)	0 (0)	
Asian	4 (6.3)	7 (12.5)	6 (9.7)	17 (9.2)	
Native Hawaiian or Pacific Islander	0 (0)	1 (1.8)	0 (0)	1 (0.5)	
Multiracial	1 (1.6)	0 (0)	1 (1.6)	2 (1.1)	
Prefer not to answer	1 (1.6)	0 (0)	1 (1.6)	2 (1.1)	
Training, No. (%)					
Intern/Resident PGY1	6 (9.4)	6 (10.7)	4 (6.5)	16 (8.8)	0.99
Resident PGY2	7	4 (7.1)	8 (12.9)	19	

	(10.9)			(10.4)	
Resident PGY3	8 (12.5)	6 (10.7)	7 (11.3)	21 (11.5)	
Resident PGY4 or above	3 (4.7)	2 (3.6)	1 (1.6)	6 (3.3)	
Fellow	5 (7.8)	8 (14.3)	9 (14.5)	22 (12.1)	
Attending/Staff	35 (54.7)	30 (53.6)	33 (52.2)	98 (53.9)	
Specialty, No. (%)					
General Internal Medicine*	39 (60.9)	29 (51.8)	29 (46.8)	97 (53.3)	0.48
Emergency Medicine	7 (10.9)	9 (16.1)	12 (19.4)	28 (15.4)	
Anesthesiology	0 (0)	1 (1.8)	1 (1.6)	2 (1.1)	
Pulmonary and Critical Care	10 (15.6)	10 (17.9)	15 (24.2)	35 (19.2)	
Cardiology	7 (10.9)	6 (10.7)	2 (3.2)	15 (8.2)	
Other Internal Medicine subspecialty	0 (0)	0 (0)	0 (0)	0 (0)	
Surgery/Surgical subspecialty	1 (1.6)	1 (1.8)	3 (4.84)	5 (2.8)	
90-Day Experience†, No. (%)					
0-10 patients	52 (65.6)	27 (48.2)	30 (48.4)	99 (54.4)	0.09
11-20 patients	14 (21.9)	15 (26.8)	17 (27.4)	46 (25.3)	
21-30 patients	5 (7.8)	9 (16.1)	6 (9.7)	20 (11.0)	
31-40 patients	2 (3.1)	2 (3.6)	3 (4.8)	7 (3.9)	
> 40 patients	1 (1.6)	3 (5.4)	6 (9.7)	10 (5.5)	
365-Day Experience†, No. (%)					
0-25 patients	29 (45.3)	24 (42.9)	24 (38.7)	77 (42.3)	0.26
26-50 patients	22 (34.4)	16 (28.6)	12 (19.4)	50 (27.5)	

51-75 patients	6 (9.4)	7 (12.5)	12 (19.4)	25 (13.7)	
76-100 patients	4 (6.3)	1 (1.8)	7 (11.3)	12 (6.6)	
> 100 patients	3 (4.7)	8 (14.3)	7 (11.3)	18 (9.9)	
Device Used, No. (%)					
Laptop/Personal computer	53 (82.8)	44 (78.6)	50 (80.7)	147 (80.8)	0.92
Mobile device	11 (17.2)	12 (21.4)	12 (19.4)	35 (19.2)	

* Includes hospital medicine/hospitalist

† Experience managing patients with septic shock

‡ P values for overall category comparisons by intervention groups calculated using Kruskal-Wallis H test.

PGY = Post Graduate Year

Response Time and Guideline Discordance

Total-time was reduced in TC (45.8s, IQR 38.3s to 56.6s, P<0.001) and increased in COL (94.2s, IQR 73.0s to 142.6s, P=0.005) compared to control (71.5s, IQR 52.6s to 100.6s) (Figure 3A). Similarly, answer-time was also reduced in TC (9.5s, IQR 7.3s to 10.0s, P<0.001) and increased in COL (56.8s, IQR 35.9s to 86.7s, P<0.001) compared to control (28.3s, IQR 20.0s to 44.6s) (Figure 3B). There was no difference in read-time (TC=37.3s vs. COL=34.5s vs. control=34.6s, P=0.46).

Compared to guideline-concordant responses, guideline discordance was associated with reduced answer-time (45.0s, IQR 22.8s to 78.6s vs.16.3s, IQR 10.0s to 38.5s, respectively, P<0.001) and total-time (89.3s, IQR 55.6s to 130.2s vs. 62.6s, IQR 45.9s to 92.1s, respectively, P<0.001). Furthermore, there was a statistically significant overall relationship between choice architecture interventions and guideline discordance (c^2 11.56, P=0.003). Using the binomial probability test, the proportion of guideline-discordant responses was increased from predicted in TC (78.6%, 65.5% to 87.6%, P=0.03) and reduced in COL (48.4%, 36.0% to 61.0%, P=0.01) assuming the control group's probability (64.1%, 51.3% to 75.1%).

Time-to-Event Analyses for Competing Risk Endpoints

Cox proportional hazards regressions were performed to assess cause-specific differences in risk of guideline discordance between intervention groups. Proportional hazards assumptions were tested for all models and met (P>0.05) based on Schoenfeld residuals. Risk of guideline discordance was increased in TC (CHR 3.38, 1.97 to 5.79, P<0.001) and decreased in COL (CHR 0.52, 0.30 to 0.93, P=0.03) (Figure 4).

Results were similar in TC (CHR 3.23, 1.80 to 5.82 P<0.001) and COL (CHR 0.54, 0.30 to 0.96, P=0.04) after excluding physicians in TC who failed to answer in the allotted time (n=8). Lastly, risk of guideline discordance was reduced among physicians with greater propensity to override intuitive thinking (high CRT score; ³2 of 3 correct answers) (CHR 0.56, 0.32 to 0.98, P=0.04) and among physicians who accurately identified the SSC initial fluid resuscitation guidelines (CHR 0.41, 0.19 to 0.90, P=0.03).

Effect Modification

CRT and both risk tolerance scales (JPI-RTS and MFS) were independently added as interaction terms to the adjusted main-effects Cox proportional hazards model. For the guideline-concordant endpoint, the effect of TC was dependent on CRT score while the effect of COL was dependent on risk tolerance by both JPI-RTS and MFS. For those with a high CRT score, the risk of a guideline-concordant answer was 7.87 (1.80 to 34.44, P=0.006) times higher in TC compared to control (Figure 4). In COL compared to control, risk of a guideline-concordant answer with a single standard deviation increase above mean JPI-RTS score (increased risk tolerance) or MFS score (decreased risk tolerance) was 2.0 (1.05 to 3.84, P=0.04) times higher and 0.42 (0.20 to 0.88, P=0.02) times lower, respectively (Figure 4). All interaction terms were non-significant for the guideline-discordant endpoint.

Measured Cognitive and Psychological Physician Characteristics

Immediately after answering the clinical vignette, self-reported acute stress compared to control was lowest in COL (5 vs. 3.5, respectively, P=0.002) with no significant difference in TC (4.5, IQR 3 to 6, P=0.23) (eFigure 1A). After adjusting for intervention group, accurate identification of SSC initial fluid resuscitation guidelines conferred the largest increase in odds of having higher stress (OR 2.39, 1.08 to 5.30, P=0.03) while reporting complete confidence in the selected answer to the vignette was associated with the largest decrease (OR 0.01, 0.00 to 0.06, P<0.001) (eTable 2). Additionally, mean CRT score was higher in TC among those who chose a guideline-concordant answer (2.42, ±0.19) compared to those who did not (1.98, ±0.14, P=0.007) (eFigure 3). Median confidence, JPI-RTS, MFS, and average CRT scores are further presented in the supplementary materials (eTable 3 and eFigure 1).

Several physician characteristics differed between men and women. Compared to men, women reported higher stress (5, IQR 3 to 7 vs. 4, IQR 2 to 6, P=0.001) and slightly lower confidence (3, IQR 2 to 3 vs. 3, IQR 2 to 4, P=0.03). Women also had lower propensity to override intuitive thinking and lower risk tolerance, as measured by the CRT (1.83, ±0.96 vs. 2.14, ±0.95, P=0.04) and JPI-RTS (18, IQR 14.5 to 21 vs. 20.5, IQR 17 to 24, P<0.001), respectively (eFigure 4).

Discussion

Utilizing two distinct choice architecture interventions, adjusted risk of failure to prescribe ≥30mL/kg of IV fluid in the first 3 hours for a patient with sepsis was increased by promoting faster decisions with a time constraint and decreased by promoting slower decisions with more fluid-volume options. In the time constraint group, the risk of guideline-concordant fluid prescribing was relatively higher among

physicians with a greater predisposition to override intuitive responses. In the choice overload group, the risk of guideline-concordant fluid prescribing was relatively higher among physicians with greater risk tolerance. While there are inherent challenges examining factors that influence decision-making as it occurs in dynamic clinical contexts, these data substantiate two proofs of concept that support future investigations in real-world settings. First, physicians are susceptible to choice architecture effects when prescribing IV fluids for patients with sepsis. Second, these effects are modified by measurable physician cognitive and psychological characteristics.

Findings from this study are consistent with previous studies demonstrating low SSC guideline concordance, associations between physician risk tolerance and variable clinical practices, and deviations in clinical decision-making associated with cognitive bias and choice architecture in other clinical conditions and circumstances.[26,27] Adding to the existing literature, our findings also suggest response time may be an important predictor, marker, or endpoint for evaluating intentional and inadvertent choice architecture effects. Although associations between response time and cognitive errors or bias remain inferential, there are credible theoretical constructs that support mechanisms by which response time may impact risk of guideline discordance. Dual Process Theory describes intuitive (System 1) and analytical (System 2) thinking,[28] the use of which may be governed by implicit detection of response conflicts.[29,30] Mechanistically, choice overload may have reduced guideline-discordance via an associated increase in the number of potential sources of decisional conflict[30,31] as indicated by increased time spent answering the clinical vignette. For example, if a physician was intuitively cued by their existing heuristics or biases (e.g. priming[7] or availability bias[7]) to prescribe fluid-boluses of 500mL or less for patients with a history of heart failure, the presence of a 250mL option and both Normal Saline and Lactated Ringers options promotes conflict between similar choices. Pausing to resolve these conflicts may provide increased opportunity for an analytical override and may also explain why acute stress was lower in the choice overload group despite having to consider more options. Paradoxically, accurate knowledge of SSC guidelines more than doubled the odds of physicians reporting higher acute stress, potentially due to conflict between opposing heuristics for managing patients with both sepsis (more fluids) and heart failure (less fluids to avoid volume overload) when guidelines are known.

Conversely, a mandatory time constraint may have increased the risk of guideline discordance by inhibiting conflict recognition or analytical engagement.[32] Notably, physicians who chose a guideline-concordant answer in the time constraint group were significantly better at suppressing intuitive responses in favor of analytical thinking, as measured by the CRT. It is also possible that other unmeasured cognitive processes may have occurred in response to each choice architecture intervention. For example, the inclusion of more choice options may also have functioned as a memory cue prompting respondents to recall guideline-recommended fluid volumes. Lastly it is important to state that optimal resuscitation targets may be unclear[33] and some decisions to prescribe guideline-discordant fluid volumes for patients with sepsis may be valid or reasonable.[34] However, this alone would not explain differences in response time and risk for guideline discordance observed across randomized intervention groups.

Findings from this study have potential clinical implications, particularly towards understanding unwarranted variation in clinical decision-making and designing effective interventions and decision aids. For example, only a few strategies to encourage deliberation and mitigate cognitive bias have been rigorously tested or proven effective in clinical contexts.[35] Effect modification associated with physician cognitive and psychological characteristics observed in this study may help explain non-uniform susceptibility to these interventions. Furthermore, modifying choice architecture to increase or decrease response time may serve as a novel framework for designing and assessing quality improvement and patient safety interventions, including in the management of sepsis and other acute care conditions.

Despite adjusting for physician cognitive, psychological, and demographic characteristics, survey-based studies using clinical vignettes may not entirely approximate real-world decision-making. Accordingly, we interpret our results as proofs of concept that support further studies in actual clinical contexts. Other limitations include a survey response rate that was relatively low but similar to some of the highest response rates among existing survey studies of physicians.[36,37] The study was also performed at two non-geographically distributed academic institutions, limiting generalizability. A major strength of our study is that we compared the effects of choice architecture interventions on both response time and guideline-discordance, adding to the significance of the findings by exploring potential mechanisms of actions that are closely linked to validated theoretical constructs in cognitive psychology and behavioral economics.

Further investigation is needed to define the mechanistic association between choice architecture, response time, cognitive bias, and clinical decision-making, corroborated in analyses of actual practice. Qualitative companion studies are needed to more closely examine factors driving clinical decisions. Lastly, findings from this study also warrant validation in future large-scale, geographically distributed, multi-institutional analyses.

Conclusion

By promoting faster or slower decision-making, time constraint and choice overload respectively increased and decreased the risk for failure to prescribe guideline-recommended intravenous fluids in a sepsis clinical vignette. These effects were modified by physician risk tolerance and predisposition towards intuitive or analytical thinking. Although physicians may sometimes rationally discount current guidelines, choice architecture may significantly impact clinical decision-making and guideline discordance for patients with sepsis.

Abbreviations

CHR = Cause-specific hazard ratio

CI = Confidence interval

COL = Choice overload intervention group

CRT = Cognitive Reflection Test

HR = Hazard ratio

IQR = Interquartile range

JPI-RTS = Jackson Personality Inventory Risk-Taking Subscale

LR = Lactated Ringer's

MFS = Malpractice Fear Scale

NS = Normal saline

PGY = Post-graduate year

SD = Standard Deviation

SSC = Surviving Sepsis Campaign

TC = Time-constraint intervention group

Declarations

Ethics approval and consent to participate. This study protocol was approved by the Colorado Multiple Institutional Review Board. A consent form was clearly displayed in the electronically distributed request to participate in the survey, indicating that consent is given by answering the questions in the survey.

Consent for publication. Not applicable.

Availability of data and materials. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests. The Authors declare that they have no competing interests.

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Figures

Clinical Vignette

A 60-year-old patient with a history of coronary artery disease and congestive heart failure (ejection fraction of 35%) presents with a chief complaint of shortness of breath. Two hours after an initial 500mL bolus of Normal Saline, on examination the temperature is 38.5°C, blood pressure 80/50 mmHg, pulse 100/min, and respiratory rate 22/min. Saturation on 2L of oxygen via nasal cannula is 96%. The patient weighs 66kg. The lower extremities demonstrate trace pitting edema to the knee. Cardiovascular and abdominal exam are otherwise normal. Lung exam reveals left basilar crackles. Laboratory exam reveals a leukocyte count of 15,000/mm^3 (15.0 x 109/L). Lactate is 4.2 mmol/L and sodium is 131 mEq/L (131 mmol/L). The remainder of the electrolytes are normal. A portable chest x-ray demonstrates cardiomegaly and faint left lower lobe patchy airspace opacities without prior films for comparison.

Which of the following would you prescribe over the next hour?

Control	Time Constraint*	Choice Overload		
I would not prescribe any additional IV fluids at this time	I would not prescribe any additional IV fluids at this time	I would not prescribe any additional IV fluids at this time		
250mL NS	250mL NS	250mL NS	1,250mL NS	2,250mL NS
500mL NS	500mL NS	250mL LR	1,250mL LR	2,250mL LR
1,000mL NS	1,000mL NS	500mL NS	1,500mL NS	2,500mL NS
1,500mL NS	1,500mL NS	500mL LR	1,500mL LR	2,500mL LR
2,000mL NS	2,000mL NS	750mL NS	1,750mL NS	2,750mL NS
		750mL LR	1,750mL LR	2,750mL LR
		1,000mL NS	2,000mL NS	3,000mL NS
		1,000mL LR	2,000mL LR	3,000mL LR

Figure 1

Clinical vignette and answer sets by intervention group. Respondents were randomized to each intervention in 1:1:1 fashion. All answer choices were presented in random order. NS presented as 'Normal Saline' and LR presented as 'Lactated Ringer's'. The vignette and question with answer choices were presented on separate pages. Figure does not represent actual display to respondents. * 10 second limit imposed to select an answer choice. There was no limit for other groups.

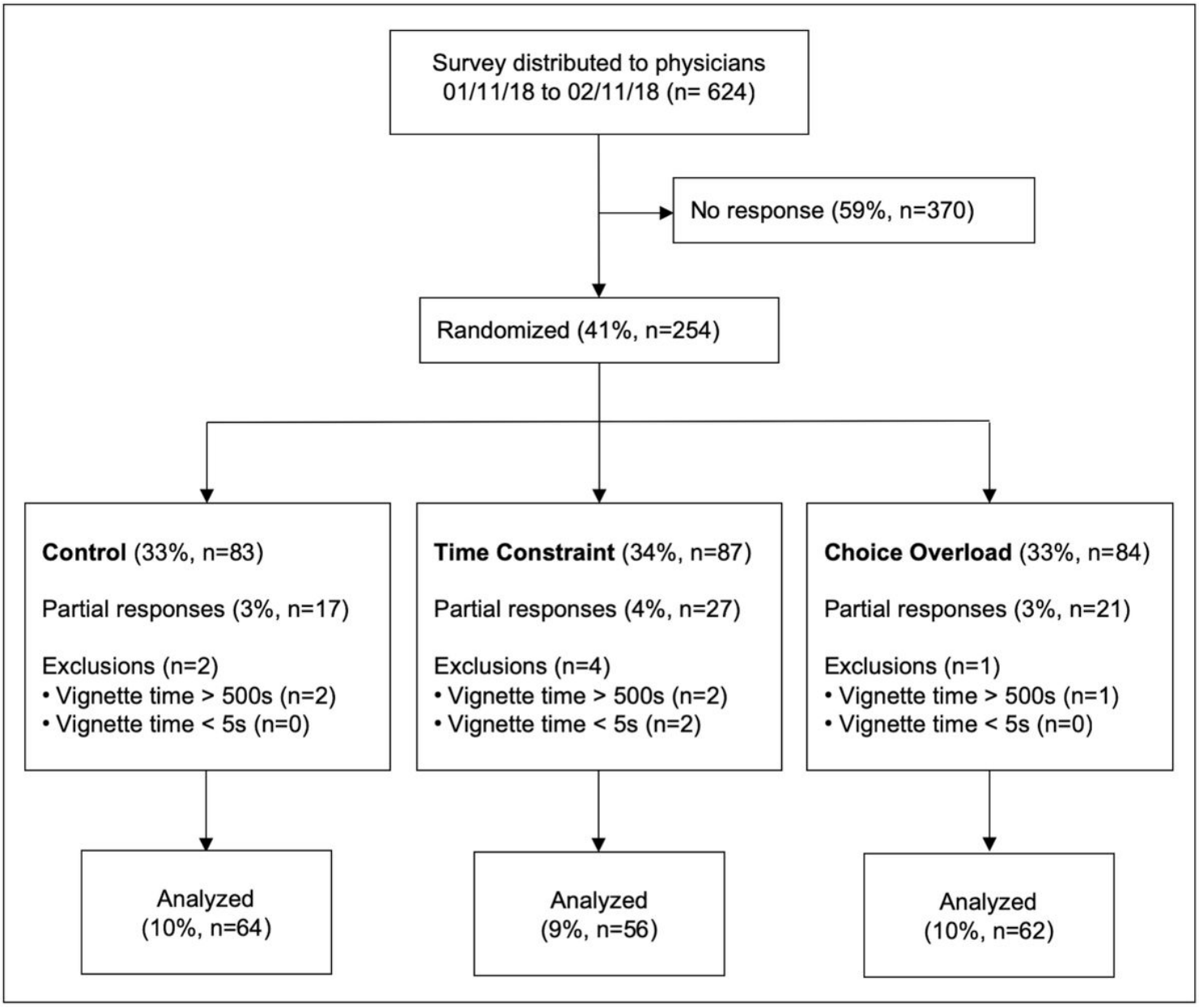

Figure 2

Physician enrollment and stratification. Vignette time is equal to sum of time spent on vignette page in addition to question and answer page. Percentages are percent of total distribution.

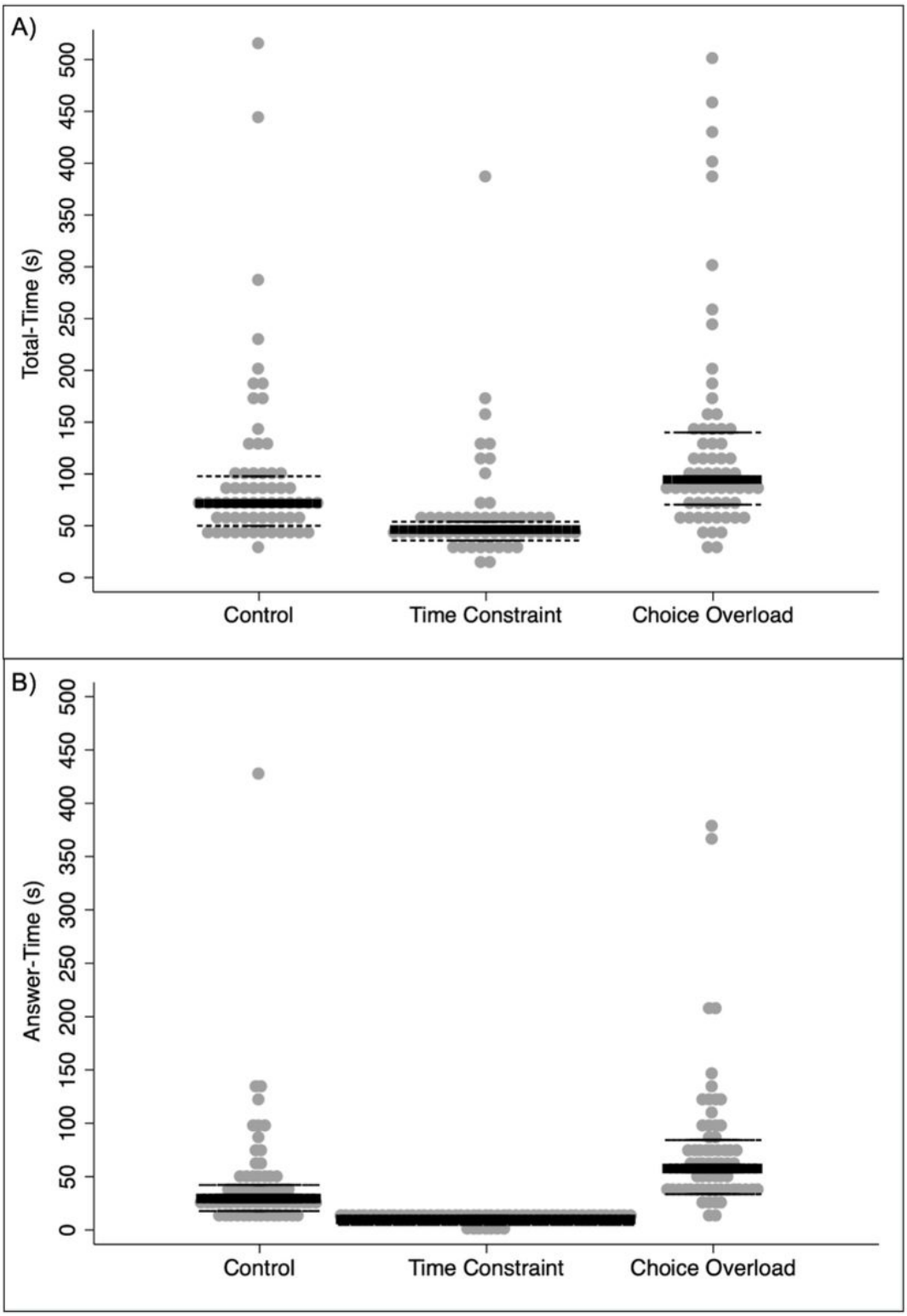

Figure 3

. Response time decreased with time constraint and increased with choice overload. A) Total-Time represents time spent reading and answering the vignette. B) Answer-Time represents time spent on the question/answer page. Differences were significant when time constraint and choice overload groups were compared to control and to each other. ■■■ = median, ┄┄ = 25th and 75th percentiles

Event	Variable Intervention	Cox Proportional Hazards Cause-Specific HR (95% CI)	Interaction Term Coefficients (95% CI) CRT Score	JPI-RTS Score	MFS Score
Guideline-Discordant Answer	Time Constraint	3.38*** (1.97-5.79)	0.76 (0.43-1.35)	0.81 (0.46-1.44)	1.02 (0.59-1.79)
	Choice Overload	0.52* (0.30-0.93)	0.78 (0.42-1.43)	0.74 (0.40-1.38)	1.06 (0.57-1.97)
Guideline-Concordant Answer	Time Constraint	1.63 (0.60-4.42)	7.87** (1.80-34.44)	1.06 (0.46-2.46)	0.62 (0.22-1.73)
	Choice Overload	0.68 (0.31-1.50)	0.90 (0.45-1.80)	2.00* (1.05-3.84)	0.42* (0.20-0.88)

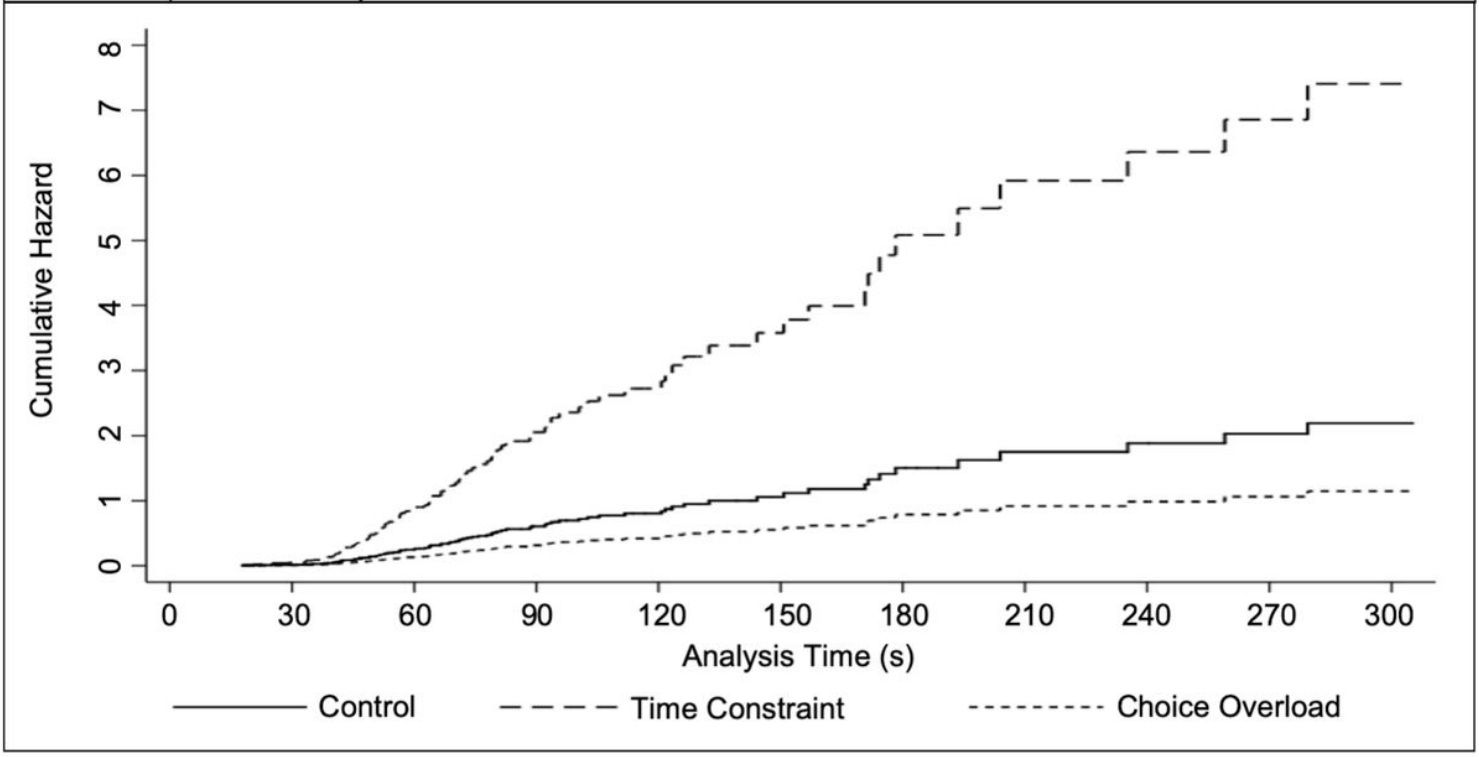

Figure 4

Increased and decreased adjusted risk for an SSC guideline-discordant answer with time constraint or choice overload. Each intervention group is compared to control (reference). Interaction term coefficients on the cause-specific HRs are also displayed. Analysis time represents total time spent reading and answering the clinical vignette. SSC = Surviving Sepsis Campaign, HR = Hazard Ratio, CRT = Cognitive Reflection Test, JPI-RTS = Jackson Personality Inventory Risk-Taking Subscale, MFS = Malpractice Fear Scale, CI = Confidence Interval * $P<0.05$, ** $P\leq0.01$, *** $P\leq0.001$

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- supplement8.pdf