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Authors

Grouse, Carrie
Waung, Maggie
Holmgren, A
et al.

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Brief Communication

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Behavioral "nudges" in the electronic health record to reduce waste and misuse: 3 interventions

Carrie K. Grouse[1], Maggie W. Waung[1], A. Jay Holmgren[2], John Mongan[3,4], Aaron Neinstein[5,6], S. Andrew Josephson[1], and Raman R. Khanna[7]

[1]Department of Neurology, UCSF, San Francisco, California, USA, [2]Center for Clinical Informatics and Improvement Research, UCSF, San Francisco, California, USA, [3]Department of Radiology, UCSF, San Francisco, California, USA, [4]Center for Intelligent Imaging, Department of Radiology and Biomedical Imaging, UCSF, San Francisco, California, USA, [5]Division of Endocrinology, Department of Medicine, UCSF, San Francisco, California, USA, [6]UCSF Center for Digital Health Innovation, UCSF, San Francisco, California, USA and [7]Division of Hospital Medicine, Department of Medicine, UCSF, San Francisco, California, USA

Corresponding Author: Raman R. Khanna, MD, UCSF School of Medicine, 10 Koret Way, Room K319 San Francisco, CA 94143-0131, USA; raman.khanna@ucsf.edu

Carrie K. Grouse and Maggie W. Waung are co-first authors.

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ABSTRACT

Electronic health records (EHRs) offer decision support in the form of alerts, which are often though not always interruptive. These alerts, though sometimes effective, can come at the cost of high cognitive burden and workflow disruption. Less well studied is the design of the EHR itself—the ordering provider's "choice architecture"—which "nudges" users toward alternatives, sometimes unintentionally toward waste and misuse, but ideally intentionally toward better practice. We studied 3 different workflows at our institution where the existing choice architecture was potentially nudging providers toward erroneous decisions, waste, and misuse in the form of inappropriate laboratory work, incorrectly specified computerized tomographic imaging, and excessive benzodiazepine dosing for imaging-related sedation. We changed the architecture to nudge providers toward better practice and found that the 3 nudges were successful to varying degrees in reducing erroneous decision-making and mitigating waste and misuse.

Key words: computerized tomography, decision support, nudge, choice architecture, overuse, waste

INTRODUCTION

One benefit of the electronic health record (EHR) is the potential continuum of integrated clinical decision support that it offers. Intrusive, high-touch decision support in the form of pop-up or similar alerts have been studied, with their strengths and weaknesses described.[1] However, choice architecture itself—the ways in which "the context in which people make decisions" is constructed, as described by Thaler and Sunstein in their book *Nudge: The Final Edition*[2]—can often have a large impact, too. In the case of the EHR, particularly regarding computerized provider order entry, choice architecture involves how orders are searched, discovered, presented, and completed; this architecture provides "nudges"—altering provider behavior "without forbidding any options"—that, in both helpful and unhelpful ways, can affect provider behavior.[2] Prior studies from Patel et al[3–6] detail nudges successfully deployed at the University of Pennsylvania within the context of a formal nudge program. There is potential to improve the practice of medicine by identifying erroneous or wasteful behaviors, and then designing and implementing targeted EHR order interventions. Here, we describe 3 interventions to the clinical ordering format where nudges in the choice architecture were unintentionally driving waste and misuse, and our restructuring of that architecture to align

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the nudges toward more clinically appropriate courses of action without pop-ups or warnings.

METHODS

University of California, San Francisco (UCSF) Health is an academic medical center with approximately 2.4 million ambulatory visits and 40 000 hospital discharges each year. Millions of orders are placed yearly through our EHR (delivered by vendor Epic Systems Corporation, Verona, WI, USA), with each order influenced by medical training and experience, as well as the subtle nudges described above. As each EHR "orderable" is designed, decisions are made regarding what it is named, how easy it is to find, alongside which orders it is presented, and so on. These decisions sometimes unintentionally create waste or even facilitate misuse, especially when providers order the wrong tests or prescribe medications in an inappropriate manner.

We identified 3 frequent erroneous ordering practices that may have been due to the choice architecture and implemented the following changes to alter electronic ordering behavior:

1. Free phenytoin level (2020–2021): The ordering of *free* phenytoin levels—an expensive send out test—leads to delays in patient care in the inpatient setting. Instead, a *total* phenytoin level is appropriate in most circumstances[7] and is available quickly, thus enabling rapid medication adjustments. Unfortunately, because "free phenytoin" is alphabetically prior to "total phenytoin", it was being presented first to providers searching for "phenytoin level".
   We removed the ability to order free phenytoin independently. In its place, we created an order panel that is presented to a provider searching for "phenytoin" or "free phenytoin". In this order panel, an explanation is given of the rare circumstances in which a free phenytoin level is appropriate and includes both total phenytoin, which is "pre-checked" and free phenytoin, which is defaulted to "unchecked", nudging the provider toward the order that is almost always correct (Supplementary Figure S1).
2. Computerized tomography (CT) abdomen/pelvis order (2013–2014): Another challenge that wasted clinician time and delayed patient care was the inadvertent ordering of a CT abdomen when a CT abdomen/pelvis study was desired. This was hypothesized to be due to CT abdomen being alphabetically prior to CT abdomen/pelvis, thus presented first.
   We changed the computerized provider order entry for "CT abdomen/pelvis" to "CT abdomen /pelvis". The extra space in front of the slash displayed "CT abdomen /pelvis" at the top of the imaging list, above CT abdomen, nudging the provider to select the first (now correct) order in the list (Supplementary Figure S2).
3. Benzodiazepine for imaging anxiety (2020–2021): Benzodiazepines are frequently ordered for procedural anxiety. Unfortunately, the default quantity for such orders was the same as the quantity for patients taking these medications on a routine basis for chronic disease; thus, providers were nudged to prescribe far more benzodiazepine pills than necessary, leading in some cases to direct patient harm when patients received these larger quantities.
   We created a new order called "Lorazepam (Ativan) tablet 0.5 mg for imaging/procedure" that appears in the ambulatory orders preference list for all ambulatory providers when they search for lorazepam (or ativan) in the orders activity (Supplementary Figure S3a). This order defaults to a quantity of 2 tablets with zero refills, as well as a default PRN comment "for anxiety (prior to imaging study or procedure)," nudging providers to prescribe the more appropriate quantity (Supplementary Figure 3b).

In the case of phenytoin, we tracked all instances of free phenytoin level and total phenytoin level ordering across both inpatient and ambulatory contexts in the 12.5 months prior to the intervention and 3.5 months following.

In the case of the CT abdomen/pelvis order entry, we tracked all instances of CT abdomen/pelvis study requests that were initially and incorrectly requested as CT abdomen alone and had to be converted to CT abdomen/pelvis studies for 6 months before and 7 months after the intervention in the case of inpatient and outpatient studies, and 10 months before and 3 months after the intervention in the case of the emergency department (ED) studies as the change occurred in the ED 4 months after the change occurred inpatient and outpatient. (Note, some CT abdomen requests are appropriate; they were excluded here, because they would not have been converted to CT abdomen/pelvis requests.)

In the case of lorazepam for procedural and imaging anxiety, we tracked all ambulatory orders for lorazepam 0.5 mg which had "MRI" or "procedure" in the indication line in the 7.5 months prior to the new order implementation, and the 6.5 months following the new order implementation. We defined an appropriate quantity as $\leq$2 tablets for this indication.

In all 3 cases, the order changes were accompanied only by general educational guidance for ordering providers (monthly EHR updates), and in the case of phenytoin an accompanying block of text within the order options menu providing general educational guidance to not order a free phenytoin level except in special circumstances.

We conducted a simple before–after analysis in each case using a chi-squared test, as well as an interrupted time series with graphed results of each intervention. The Institutional Review Board at UCSF approved this minimal risk, no human contact study with a waiver for informed consent.

All analyses were completed using Stata version 14 (College Station, TX, USA).

RESULTS

Results for all three nudges are summarized in Table 1.

Phenytoin level

Prior to the intervention, total phenytoin level orders comprised 553 of the 604 Phenytoin level orders, for a "correct" rate of 92%; after the intervention, they comprised 149 out of the 149 orders (100%, $P < .001$). In our interrupted time series analysis, compared to the preintervention trend, there was an improvement of 8% at the time of intervention ($P < .001$), and no postintervention trend ($P = 1.00$) (Figure 1).

CT abdomen/pelvis

Prior to the intervention, CT scans of the abdomen and pelvis were ordered correctly 4675 out of 5198 total times (89%); after the intervention, they were ordered 4955 out of 5192 times (95%, $P < .001$). Compared to the preintervention trend, in the inpatient and outpatient (non-ED) settings, there was a 4.1% increase at the

Table 1. Interrupted Time Series Analysis of the Three Nudges

	Pre-nudge implementation* Percent (95% CI)	Immediately after implementation* Percent (95% CI)	Post-nudge trend* Percent/month (95% CI)
Correct phenytoin order	92.0 (91.6%–92.4%)	100.0 (99.6%–100%)***	+0 (-0.0%–+0.0%)
Correct CT order, non-ED patients	90.3 (88.8%–90.6%)	94.4 (92.9%–95.9%)***	+0.8 (+0.5%–+1.1%)***
Correct CT order, ED patients	89.6 (88.2%–90.9%)	94.5 (91.4%–97.6%)**	+1.8 (+0.0%–+3.7%)†
Lower dose lorazepam with fewer pills	13.1 (13.0%–13.1%)	16.4 (16.04%–16.7%)***	+2.2 (+2.1%–+2.3%)***

Note: Nudges happened at different times; all data above are normalized to the nudge in question.
Correct phenytoin order: preperiod, 12.5 months; postperiod, 3.5 months.
Correct CT order, non-ED: preperiod, 6 months; postperiod, 7 months.
Correct CT order, ED: preperiod, 10 months; postperiod, 3 months.
Lower dose lorazepam with fewer pills: preperiod, 7.5 months; postperiod, 6.5 months.
CI: confidence interval; CT: computerized tomography; ED: emergency department.
†$P > .05$.
**$P < .01$.
***$P < .001$.

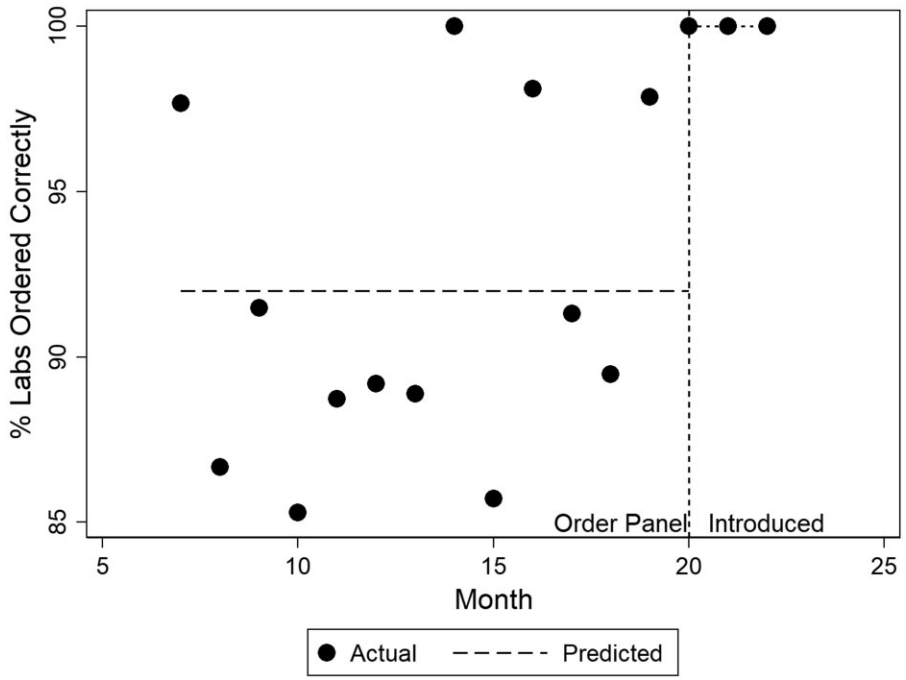


Figure 1. Ordering of total phenytoin as a percentage of total orders for phenytoin (total phenytoin and free phenytoin) over time in months. The dashed vertical line is the month at which the modified phenytoin order panel was implemented.

time of the intervention ($P < .001$), and a 0.8%/month improvement postintervention ($P < .001$); in the ED, there was a 4.9% increase at the time of intervention ($P = .002$) and a nonsignificant trend toward improvement postintervention of 1.9%/month ($P = .053$) (Figure 2).

Lorazepam for sedation

Prior to the intervention, orders for 2 or fewer lorazepam 0.5 mg tablets for an indication of procedural or imaging-related anxiety comprised 359 of the 2791 orders for any benzodiazepine with this indication (12.9%); after, they were 504 of 2266 such orders (22.2%, $P < .001$). In our interrupted time series analysis, compared to the preintervention trend, there was a significant improvement of 3.3% at the time of the intervention ($P < .001$) and further improvement postintervention of 2.2%/month ($P < .001$) (Figure 3).

DISCUSSION

In these 3 interventions, aspects of the choice architecture were nudging providers toward waste or misuse. By changing the direction of these nudges—in one case, via making the less appropriate order more difficult to find and use; in the second case, by making the more frequently desired imaging easier to find; and in the final case, by presenting an easy to find alternative—we attempted to nudge providers toward reduced waste and misuse. These nudges were successful to varying degrees.

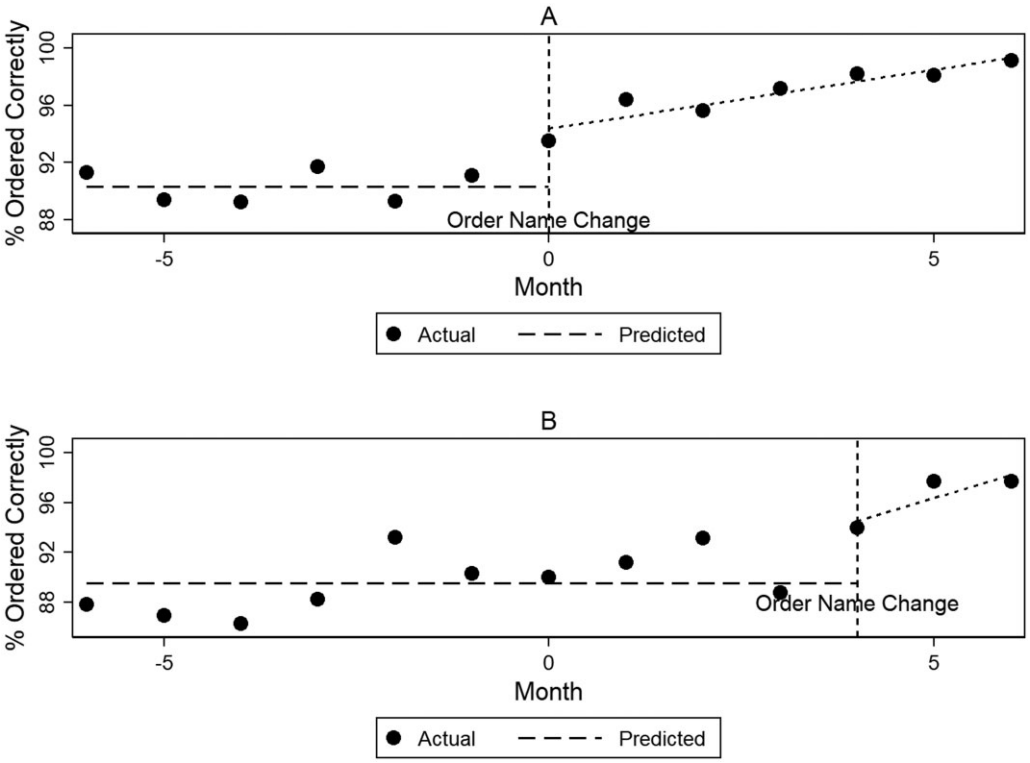


Figure 2. Ordering of computerized tomographic (CT) abdomen and pelvis as a percentage of total orders for CT scans of the abdomen (CT scans abdomen and pelvis and CT scans of abdomen only) over time in months, in the non-emergency department areas (A) and the emergency department (B). The dashed vertical line in A and B are at 0 and 4 months because the renamed order was introduced in each area at those respective times.

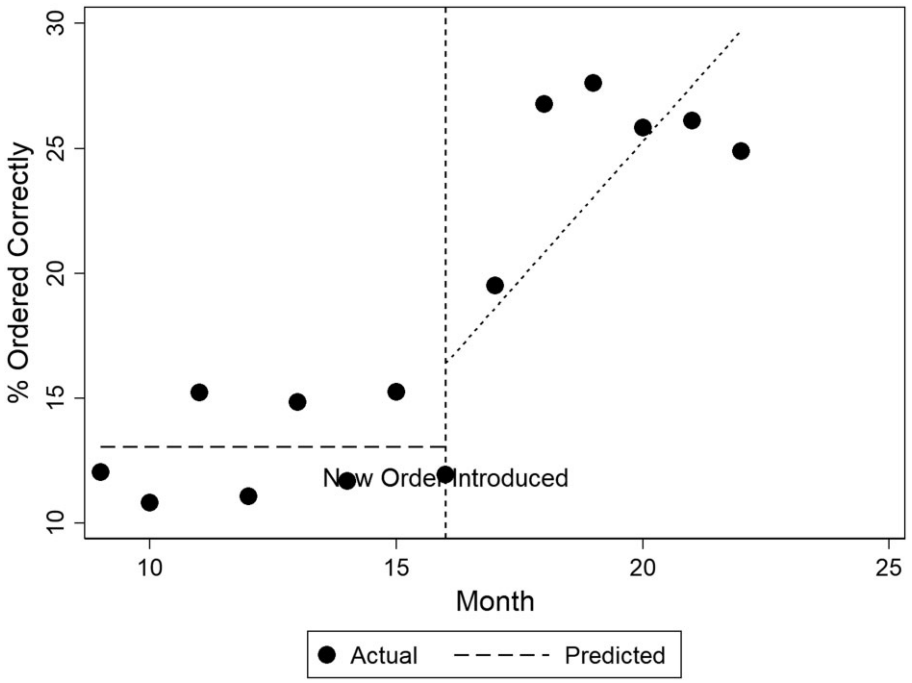


Figure 3. Ordering of 2 or fewer lorazepam tablets for imaging sedation as a percentage of total Benzodiazepine orders for sedation over time in months. The dashed vertical line represents the time at which the new order with a reduced number of lorazepam tablets was implemented.

As compared to interruptive alerts, nudges in the EHR literature have not been as well described, though Patel et al[3] have established a "Nudge" group at University of Pennsylvania with several associated successes. Additionally, one group demonstrated that prioritizing the complete blood count (CBC) above CBC with differential for the ED EHR resulted in decreased inappropriate ordering of CBC with differential compared with an educational intervention.[8] Changing default opioid quantity settings in the EHR has been demonstrated by a number of groups to reduce the amount of prescribed opioids.[9–13] Our experience adds to this literature in a few ways by indicating ways in which the choice architecture could be adjusted to beneficial ends.

Our approaches were variable in their targeting. The phenytoin lab order redesign significantly increased the burden of ordering a free phenytoin level, making the "right thing" easier to do and the "wrong thing" harder—what Thaler and Sunstein refer to as "sludge".[2] (The redesigned order did contain some education within the body of the orders, though in our experience providers tend to ignore these in the absence of "nudges.") The CT naming change increased the ease of finding the correct order through first item preference. The sedation for procedure or imaging change improved the ease of ordering a low-dose sedative with 2 or fewer pills but did not add to the cognitive burden of incorrect ordering. The relative benefit of any of these approaches could be studied in future interventions that compare these approaches.

The final change was successful in terms of nudging providers ordering sedation for Magnetic Resonance Imaging (MRI) or procedures to order 2 or fewer pills of low-dose lorazepam; however, this intervention improved from a very low baseline and the "correct" amount of nudging is not clear. For example, providers may order 2 pills of diazepam or alprazolam or another benzodiazepine and arguably this would still be appropriate, and it may not be desirable to reach 100% "correct" ordering. Additionally, we may need to incorporate nudges for these other medications to reduce all excess benzodiazepine prescribing for MRI or procedural sedation.

Of note, our overall approach did not involve any additional specific education or instruction other than general educational guidance. A nudge can itself be an educational strategy, or include education in line as we did in the case of phenytoin; individuals looking to place the correct order could see, at the time of ordering, why a given order was preferred. Future research could examine whether nudges that include in line education are more effective than those without.

In the case of Phenytoin, our nudge consumed an estimated 6 h of institutional time to implement, inclusive of the time of all those involved to discuss (via email) the change with stakeholders and our EHR analysts, the time for the change to be built and test the change, and the time to enable it in the EHR. In the case of the CT orders the total time involved was estimated at 3 h; in the case of the lorazepam orders, 16 h. The benefit of these interventions must be balanced against the costs of their implementation.

Our current study has important limitations. All interventions were conducted at a single site with a single EHR. No adjustments were conducted or practical given the limitations of available data sources, though we do not believe that there have been any appreciable changes in the patient population with these specific needs in the study time periods. Additionally, although our interrupted time series analyses should have mitigated the impact of secular trends, we cannot fully rule them out in our current design. Given the time frames of the pre-post periods for the 3 different nudges, it was not possible to have identical time frames pre-post, nor to do hierarchical analyses clustered by provider to model behavior change or provider type (resident vs attending vs advanced practice provider) to better understand the pattern of impact. In future "nudge" studies, longer follow ups and improved intra-provider and provider type comparison will help to characterize these nuances. Nudges can also be too successful, if for example our interventions eliminated even appropriate free phenytoin orders, caused patients to get a CT abdomen/pelvis even when a CT abdomen was appropriate, or resulted in insufficient lorazepam for procedural sedation. We were unable to assess for these consequences in the current study. We additionally could not assess outcomes such as sedation-related side effects pre- and post- the lorazepam order changes, nor do we have formal data on user acceptability of our order changes other than the absence of complaints or changes requested to revert the orders to their old format. Against these limitations, our study has significant strengths, including a comparison of several different "nudge" interventions and a demonstration of possible efficacy even at very high rates of baseline efficacy in 2 cases (85% or more correct orders for both phenytoin level and CT abdomen/pelvis), suggesting that improvement may be possible even to 100%; though as noted above, 100% may not be desirable in all cases.

In summary, we implemented 3 changes in our EHR choice architecture to realign nudges away from waste and misuse and found significant efficacy in all 3 interventions. We believe that greater attention to choice architecture and nudging presents a method for improving quality of care without the worsening cognitive burden associated with interruptive alerts. More study is required to further delineate what makes for effective EHR-based nudges and where they can best be deployed.

FUNDING

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AUTHOR CONTRIBUTIONS

CKG—co-wrote manuscript, idea for and implementation of intervention 3. MWW—co-wrote manuscript, idea for and implementation of intervention 3. AJH—edited manuscript for content, provided statistical support. JM—edited manuscript for content, idea for and implementation of intervention 2. AN—edited manuscript for content, idea for and implementation of intervention 2. SAJ—edited manuscript for content, idea for intervention 1. RRK—co-wrote manuscript, compiled statistical analysis, idea for and implementation of intervention 1.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

CONFLICT OF INTEREST STATEMENT

CKG has research grants from Siemens. JM has research grants from GE and Siemens, and personal royalty income from GE. His spouse has employment with AbbVie and Annexon Biosciences. AN has served as advisor and received consulting fees from Roche, Sanofi, Medtronic, Eli Lilly, Steady Health, and Intuity Medical, has served as advisor (no payment) for Tidepool, has received research grants

from Eli Lilly, Pfizer, Royal Philips, Commonwealth Fund, and Cisco, and has received author and speaker honoraria from TCOYD, Medscape/WebMD, and AcademyHealth. RRK has received licensing income from Voalte, Inc, which is owned by Baxter, Inc. None of the above companies or agencies played any role in the design, implementation, or write up of the current study, and no other competing interests are identified.

DATA AVAILABILITY

The data for this study were collected during routine patient care, is from the UCSF EHR and limited in scope to these studies and is not archived online in any format.

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