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Requiring Clinical Justification to Override Repeat Imaging Decision Support: Impact on CT Use

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Abstract

OBJECTIVE—The purpose of this study was to determine the impact of requiring clinical justification to override decision support alerts on repeat use of CT.

SUBJECTS AND METHODS—This before and after intervention study was conducted at a 793-bed tertiary hospital with computerized physician order entry and clinical decision support systems. When a CT order is placed, decision support alerts the orderer if the patient's same body part has undergone CT within the past 90 days. The study cohort included all 28,420 CT orders triggering a repeat alert in 2010. The intervention required clinical justification, selected from a predetermined menu, to override repeat CT decision support alerts to place a CT order; otherwise the order could not be placed and was dropped. The primary outcome, dropped repeat CT orders, was analyzed using three methods: chi-square tests to compare proportions dropped before and after intervention; multiple logistic regression tests to control for orderer, care setting, and patient factors; and statistical process control for temporal trends.

RESULTS—The repeat CT order drop rate had an absolute increase of 1.4%; 6.1% (682/11,230) before to 7.5% (1290/17,190) after intervention, which was a 23% relative change (7.5 – 6.1) / 6.1 × 100 = 23%; $p < 0.0001$). Orders were dropped more often after intervention (odds ratio, 1.3; 95% CI, 1.1–1.4; $p < 0.0001$). Statistical control analysis supported the association between the increase in the drop rate with intervention rather than underlying trends.

CONCLUSION—Adding a requirement for clinical justification to override alerts modestly but significantly improves the impact of repeat CT decision support (23% relative change), with the overall effect of preventing one in 13 repeat CT orders.

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Keywords

clinical decision support; CT; informatics; repeat testing

Electronic clinical decision support (CDS) promises to enhance evidence-based practice; reduce unnecessary, unsafe, or otherwise inappropriate testing; improve quality; and reduce waste [1]. In medical imaging, CDS tools are typically triggered at the time of order entry to guide ordering providers in selecting the optimal imaging strategy (or no imaging at all) [1]. Although best practices for effective imaging CDS may be debated, the successful implementation and early impact of CDS, including systems guiding imaging orders [2–6], has led to the incorporation of CDS provisions into two sets of federal regulations. The first provides modest financial incentives for adoption of CDS as a major focus of meaningful-use stage II regulation for health care information technology [7], and the second mandates the use of imaging CDS for targeted ambulatory procedures beginning January 1, 2017, as part of the Protecting Access to Medicare Act of 2014 [8].

Repeat imaging is common, an uncertain proportion of which likely represents over-use [9–11]. Overuse contributes to the waste in health care that cost the United States up to $226 billion in 2011 alone [12] and, in the case of CT examinations, exposes patients to unnecessary and potentially harmful ionizing radiation [13]. Early work on the impact of CDS in reducing redundant imaging is promising. In one study, CDS led to the cancellation of 5% of repeat CT orders [14]. However, users chose to override and thus ignore 95% of the repeat CT CDS alerts and proceed with the CT request, highlighting a potential opportunity to find strategies to optimize the impact of CDS on repeat testing. One such strategy reported in the non-imaging decision support literature requires users to document a clinical justification to override CDS alerts [15]. Such interventions were found to have an 11-fold increase in the odds of modifying physician behavior compared with information-only CDS alerts [16]. Therefore, our objective was to determine the impact of requiring clinical justification to override decision support alerts on repeat use of CT.

Subjects and Methods

Study Site

This prospective, institutional review board-approved, HIPAA-compliant before and after intervention study was performed in a 793-bed tertiary academic medical center. Informed consent was waived for retrospective chart review. At the study institution, a computerized provider imaging order entry system (Percipio, Medicalis) with embedded CDS requiring affiliated-physician electronic signature on all imaging orders supports performance of more than 500,000 annual radiologic examinations [17]; imaging orders cannot be placed without using this system.

At the study institution, a user's role in ordering imaging can vary according to payer credentialing requirements and care setting. Support staff (administrative staff or nursing) cannot order examinations without a countersignature from an authorized provider, and attending physicians are always authorized providers. Midlevel providers (interns, residents, fellows, physician assistants, and nurse practitioners) are considered authorized providers able to order imaging examinations without countersignature in the inpatient and emergency department care settings, but in outpatient settings they are not authorized providers and need a countersignature. Most inpatient imaging orders are entered by interns, typically after discussion with more senior physicians, including residents, fellows, and attending physicians; most emergency department imaging orders are entered by residents with clinical oversight provided by fellows and attending physicians, and the vast majority of outpatient orders are entered by attending physicians and their support staff.

A repeat imaging request (defined by an institutional multidisciplinary expert panel as a patient's same body part having been imaged with the same modality within the previous 90 days) generates a real-time repeat CDS alert. An information-only repeat CDS alert deployed in December 2009 enabled the provider to override the alert and proceed with the order (Fig. 1A) or drop (cancel or abandon) it [14].

Intervention and Study Cohort

The intervention consisted of requiring a clinical justification to override a repeat CT CDS alert. If an orderer chose to ignore a repeat CT CDS alert, he or she was presented with a second screen requiring the selection of one or more clinical justifications from a predetermined menu (Figure 1B) to complete the order; otherwise the order was dropped. The list of clinical justifications was determined by a multidisciplinary panel from our institution's physician leadership because no precedents existed in the literature.

The intervention was implemented May 28th, 2010. Assuming a baseline 5% rate of dropped orders with information-only repeat CT CDS, a total sample size of 16,304 repeat CT orders was needed for 80% power to detect a 20% relative increase in dropped orders in response to the intervention with a $p < 0.05$. Thus, orders triggering repeat CT alerts from January 1 through May 27, 2010, constituted the preintervention study cohort ($n = 11{,}230$), and those entered from May 28 through December 31, 2010, the postintervention study cohort ($n = 17{,}190$) (Fig. 2). Because the training year runs from July to June, interns, residents, and fellows in the preintervention group would have an average of 6 more months of training than those in the postintervention group. However, this difference was tempered by the tighter clinical oversight of these trainees, particularly the interns, by more senior physicians at the beginning of the new academic year.

Data Collection

For each imaging order, the order entry system records the ordering provider, care setting (emergency department, inpatient, specialty clinic, primary care, or outpatient cancer center), orderer role (authorized provider, nonauthorized provider, or support staff), examination type (e.g., CT, MRI), and order status (created, cancelled, expired, or performed); this information is stored in a database (SQL Server, Microsoft).

Statistical Analysis

The primary outcome was dropped repeat CT orders, and three statistical methods were used: chi-square, multiple logistic regression, and statistical process control.

Unadjusted chi-square analysis compared unadjusted proportions of repeat CT orders dropped before and after intervention. Effect size, or relative change, was calculated by dividing the difference in proportions of repeat CT orders dropped between the before and after intervention periods by the proportion for the preintervention period. Stratified analysis was performed for care setting and orderer role subgroups and a two-sided p value of < 0.05 was used to determine statistical significance.

Multiple logistic regression was used to analyze the impact of the justification requirement while controlling for potentially confounding variables of care setting, orderer role, and patient age and sex. This method also measured the impact of care setting and orderer role subgroups and a two-sided p value of < 0.05 was used to determine statistical significance.

Statistical process control analysis used a p-subtype chart because the outcome was dichotomous (order dropped or not dropped) and the sample size varied by time interval [18, 19]. The week-of-year was assigned using weeks beginning on Sunday, with the first Sunday of the year being week 2 and the observation period running from week 1 through week 52 of 2010. The centerline represents the mean proportion of repeat CT orders dropped at baseline. The upper and lower control limits reflect the inherent variation in the data and were calculated as ± 3 SD of the centerline proportion [18, 19]. This chart was then monitored for evidence of significant change using standard statistical process control rules, including "special cause variation" [19].

The secondary outcome was the frequency distribution of clinical justifications by orderer role. All statistical analysis was performed using JMP Pro, version 10.0 (SAS Institute). Because of a programming error, justifications for overriding repeat CT CDS alerts were not collected for 6% (908/14,992) of completed repeat CT orders during the postintervention period; however, this error did not prevent capture of repeat CT orders or impair identification of any orders as dropped or completed. Because 68% of the missing data were for orders placed in the emergency department, statistical analyses were conducted both with and without this care setting; orders with missing data were not reclassified and remained in the postintervention group.

Results

Study Cohort

The final study cohort was the 28,420 CT orders (11,230 preintervention and 17,190 postintervention) that triggered repeat imaging CDS between January and December 2010. Repeat CT orders were begun for 6800 unique patients in the preintervention cohort and 9460 patients in the postintervention cohort. The cohorts were similar in sex mix, with 53% (3627/6800) women in the preintervention cohort and 53% (5059/9460) women in the postintervention cohort, and had a mean age of 61 years in each cohort (14-year SD in the preintervention cohort and 15-year SD in the postintervention cohort). Completed repeat CT orders accounted for 22% (25,548/114,807) of all completed CT orders in 2010 (preintervention, 23% [10,548/46,796] and postintervention, 22% [15,000/68,011]; p = 0.053).

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Dropped Repeat CT Orders

Unadjusted chi-square analysis—Of the 11,230 CT orders triggering the repeat imaging CDS alert during the preintervention period, 6.1% (682) were dropped before completion in the order entry system; 7.5% (1290/17,190) of the CT orders were dropped after intervention (Fig. 2 and Table 1). The absolute dropped rate change of 1.4% (7.5–6.1%) corresponded to a statistically significant 23% effect size, or relative change ([7.5 – 6.1] / 6.1 × 100 = 23%; $p < 0.0001$). Analysis with the emergency department setting removed yielded similar results, with an 18.3% effect size (preintervention, 6.0% dropped [634/10,589]; postintervention 7.1% dropped (1126/15,889); $p = 0.0004$). Using the 1.4% absolute increase in repeat CT order drop rate, we estimate 246 orders (17,190 orders in the postintervention cohort × 1.4%) were cancelled in association with the intervention. This corresponds to a 0.4% (246 / 246 + 68,011) decrease in CT volume, or 35 fewer CT orders per month in the postintervention period.

Within specific care settings and compared with information-only repeat imaging CDS, requiring justification had the greatest impact in the emergency department, with a 68% effect size, and the smallest impact for inpatients, with a 17% effect size (Table 1). The impact of requiring justifications was also dependent on the orderer's role, generating a 36% effect size for authorized providers and a 23% effect size for support staff (Table 1). This study was powered for the overall impact of requiring justification to override repeat imaging CDS alerts on dropped CT orders; subanalyses for setting, orderer, and completed repeat CT orders as a proportion of all completed CT orders were underpowered to find statistically significant changes.

Multiple logistic regression—CT orders triggering repeat imaging CDS alerts during the postintervention period had 1.3 times the odds of being dropped when compared with CT orders in the preintervention period (95% CI, 1.1–1.4, $p < 0.0001$). Care setting and orderer role were additional independent predictors of dropping an order ($p < 0.0001$ for both, Table 2). When controlling for the intervention and orderer role, primary care clinics were the care setting with the highest odds ratio (6.9, 95% CI 5.1–9.2), and when controlling for the intervention and care setting, nonauthorized providers were the role with the highest odds ratio (1.8, 95% CI 5.1–9.2). Neither patient age nor gender were significant predictors of dropped orders ($p = 0.719$ and $p = 0.961$, respectively) and therefore they were dropped from the final model. However, this did not change the odds ratios for the other variables (Table 2).

Statistical process control—Analysis of the control chart (Fig. 3) showed that the increase in proportion of dropped repeat CT orders did not begin until after the intervention and that this change was statistically significant as shown by a run of more than 8 consecutive points above the centerline [19].

Distribution of Justifications for Repeat Imaging

The clinical justification for repeat imaging was captured in 94% (14,084/14,992) of repeat CT orders completed after the intervention (the remaining 6% were missing data). Although clinical justification selection varied according to orderer role (Table 3), "established protocol" (e.g., restaging malignancy) was the most common justification overall (7110/14,992, 47%) and for each orderer type individually. The least common selection overall was "patient preference/request" (77/14,992, 0.5%).

Discussion

Requiring clinical justification to override or ignore a repeat CT clinical decision support alert was associated with the elimination of one in 13 CT orders in patients who underwent CT of the same body part in the previous 90 days. Our intervention had a significant but modest (1.3 odds ratio) impact on reducing repeat CT orders compared with an information-only repeat CT CDS alert that could be ignored by the ordering provider without providing a clinical justification (7.5% and 6.1% dropped, respectively; 23% relative change). Completed repeat CT orders decreased as a proportion of all completed CT orders (23% preintervention to 22% postintervention), although this difference was not statistically significant ($p = 0.053$). The intervention was associated with an average of 35 fewer CT orders being placed each month. Statistical process control charts showed that the increase in proportion of dropped repeat CT orders did not begin until after the intervention and confirmed the statistical significance of the change. Control chart analysis also supports the association of dropped orders with the requirement for justification to override repeat CT orders rather than other underlying trends. Our findings suggest that relatively simple enhancements to information- only CDS alerts that create consequences for overriding automated computerized alerts may improve the impact of CDS on reducing potentially redundant CT examinations with only incremental interruption to provider workflow.

Although decision support interventions requiring clinical justification to override automated alerts have been published [16], their use for imaging has not been reported. Typical CDS interventions provide realtime education at the time of clinical decision making but can easily be ignored by the ordering provider [2, 14]. Our findings support the notion that these information-only CDS interventions are unlikely to optimize provider test-ordering practices [20, 21]. A few interventions use a "hard stop," preventing users from placing orders that conflict with evidence presented in the CDS until completion of additional, more intrusive software-enabled workflows, such as requiring responsible clinicians to personally log in and order examinations rather than relying on proxy ordering by nonclinician support staff [5] or mandating peer-to-peer consultation to override alerts [6]. However, those who implement CDS are cautioned to avoid hard stop interventions in all but the most dire circumstances [22] because physicians strongly resist such interventions [23] and are more likely to ignore serious, life-threatening alerts when alert presentation does not differ by potential clinical impact [24]. Interventions with a clinical justification requirement to override CDS alerts may serve as a good compromise, increasing the impact of information-only CDS while avoiding more intrusive workflow barriers to the ordering process. Our findings are similar to other interventions in which requiring clinical justifications improved adherence to inpatient venous thromboembolism prophylaxis guidelines [25], reduced repeat inpatient laboratory tests [26], and increased the use of statin therapy in outpatients with dyslipidemia [27]. Our data suggest such interventions may be generally applicable in helping change physician behavior to improve quality and reduce waste.

Our findings also strengthen the evidence that CDS-enabled interventions can serve as useful tools to decrease health care costs and increase appropriateness of care. In the short term, health care organizations, provider groups, and payers may be able to substitute CDS-enabled interventions for much more onerous prior authorization programs, diminishing time demands and workflow interruptions for patients and providers. In the long term, as new health care payment models shift financial risks from payers to providers, CDS-enabled tools may provide cost-effective solutions to health care resource management while improving the quality of care.

Care setting was a significant predictor of the impact of repeat CT CDS alerts, with primary care having the highest rate of dropped repeat CT orders both before and after intervention as well as the largest absolute difference between before and after intervention repeat CT drop rates. However, the largest effect size, 68%, was seen in the fast-paced emergency department, where 97% of all repeat CT orders and all dropped orders were entered by authorized providers. This highlights an additional opportunity for influencing physician behavior through health care information technology; requiring a clinical justification to override a CDS alert may help the orderer to further consider the medical necessity of repeat imaging.

Orderer role was also a significant predictor of the intervention's impact, which was strongest for authorized providers in terms of absolute drop rate difference (1.9%) and effect size (36%), although nonauthorized providers dropped the highest percentage of orders before and after the intervention. The impact of the justification requirement was proportional to an orderer's degree of independence, with the greatest impact for authorized providers and least for support staff. Authorized providers, directly responsible for diagnostic and treatment plans, have the authority to change plans in response to CDS. Support staff lack such authority and may be reluctant or not have a timely opportunity to bring CDS information to the attention of the relevant ordering provider.

The requirement for clinical justification to override repeat CT CDS alerts not only increased the impact of CDS, it also provided information on why providers repeat CT examinations. Using a predetermined menu for the justifications produced interpretable data compared with allowing users to enter free text in the response, which may produce inappropriate or irrelevant entries as seen in a study of warfarin drug-drug interaction alerts in which 80% of free text justifications were inappropriate [28]. Including "none of the above" on the menu enabled providers to avoid inaccurate justification choices. "Established protocol" (e.g., restaging malignancy) was the most common selection for all orderers, chosen for 47% (7110/14,992) of all completed orders. Otherwise, clinical justifications varied by orderer role. Authorized providers selected "onset of new clinically significant symptoms and "worsening of previously noted symptoms" more often than other groups, consistent with their direct interactions with patients. Support staff chose either "established protocol" or "none of the above" 86% (4501/5237) of the time, consistent with their lack of clinical interaction and training. Nonauthorized providers' selections averaged the trends of the two other groups. Our findings suggest that repeat CDS alerts in oncology patients undergoing restaging CT may have low yield for reducing redundant CT. Eliminating these low-yield repeat CDS alerts may help reduce alert fatigue, a well described phenomenon in the literature [29].

Our study had several limitations. Because the study design was before and after rather than a randomized controlled trial, we cannot control for changes in orderer behavior due to factors other than our intervention. However, no other interventions to reduce repeat CT were introduced at our institution during the study period and the postintervention period was relatively short, thus such factors are unlikely to have significantly affected our findings. Additionally, the statistical process control analysis showed that the increase in dropped repeat CT orders began after the implementation of the intervention and thus significant change in proportion of dropped orders was unlikely to be explained by other underlying trends [19].

Clinical justifications were not collected for 6% of postintervention period orders. If this information was missing because the justification selection screen did not display, the ordering process would be identical to the preintervention period, and we would underestimate our intervention's impact. If the justification selection screen displayed but did not record the orderer's selections, impact calculations would be correct, but the frequency distribution of justifications would be incorrect. In either scenario, we believe our conclusions remain valid.

This was a single-institution study, and it may not generalize to sites with different patient populations, practice patterns, or health care technology infrastructure. Because of the timing of our study, house staff (interns, residents, and fellows) in the preintervention cohort had 6 months more experience than those in the postintervention cohort, potentially biasing our results. However, we believe any such systemic error would bias against our intervention having an effect because the amount of attending physician and more senior house staff clinical oversight for junior house staff follows a reverse pattern, with greater oversight at the beginning of an academic year and less at the end. Moreover, house staff account for the minority of outpatient orders and interns only order a small number of emergency department examinations.

We have likely underestimated the impact of the clinical justification requirement because some orders are initiated by support staff, a role that has little authority to cancel orders based on CDS. Our CDS design could not assess whether support staff responded to CDS after consulting an attending physician or they were acting independently.

A substantial portion of short-interval repeat CTs at our institution are performed for restaging patients with known malignancy after treatment (i.e., established protocol) and thus unlikely to be affected by CDS. Therefore, we are likely underestimating the impact of our intervention on nonrestaging CT studies.

It is unclear whether our findings generalize to repeat testing with other imaging modalities; it is possible repeat CDS was effective because of the awareness of potential harm of ionizing radiation with recurrent CT use.

We did not conduct a user satisfaction survey or other comprehensive evaluation of the intervention's impact on provider workflow and perception of CDS within the order entry system. Anecdotally, referring physicians consulted while designing the intervention and after its implementation described the justification requirement as familiar and often seen when entering nonimaging orders.

We did not assess the appropriateness of completed or dropped repeat CT orders. However, no evidence of harm from dropped CT orders was found in our quality assurance databases or patient complaint records. The observed decrease in imaging thus supports the notion that some portion of repeat imaging was likely inappropriate or unnecessary.

Our data highlight areas for further investigation into CDS best practices. Because the impact of our intervention was proportional to orderers' degree of independence, repeat imaging CDS may be optimized by consistently presenting alerts to authorized providers, either at the time of order entry or at electronic signature if these providers choose to take advantage of proxy workflows in which support staff initiate imaging orders on their behalf. If CT orders placed for established oncology protocols were exempted from repeat CT CDS, our data suggest that nearly half of nonactionable alerts would be avoided and alert fatigue would be reduced. A chart review to determine the actual reason an authorized provider ordered a repeat CT when "none of the above" was selected as a justification could produce a more comprehensive menu of clinical justifications and identify other indications that should suppress repeat CT CDS alerts. Completed repeat CT orders after intervention decreased as a proportion of all completed CT orders in our study, although the decrease was not statistically significant ($p = 0.053$), likely due to our study being insufficiently powered to detect the difference. We powered this study to detect a change in portion of dropped CT orders.

Although we show CDS can reduce potentially redundant imaging and unnecessary radiation exposure, these benefits must be balanced with the additional workflow burden to the ordering provider. When considering workflow, the potential for health systems and provider groups to leverage the impact of such CDS-enabled interventions in payer negotiations to avoid much more onerous preauthorization workflow interruptions for ordering providers must also be considered. Thus, implementation of CDS-enabled interventions would benefit from discussions to help balance the workflow burden to providers and potential benefits to patients, health systems, and payers.

Conclusion

Requiring clinical justification to override a repeat CT clinical decision support alert and place an order for redundant imaging prevented one in 13 repeat CT orders, modestly but significantly enhancing the impact of an information-only CDS alert that prevented one in 16 repeat CT orders ($p < 0.0001$). Future research may show that similar interventions benefit other clinical decision support initiatives, decreasing unnecessary testing and improving the quality and safety of patient care.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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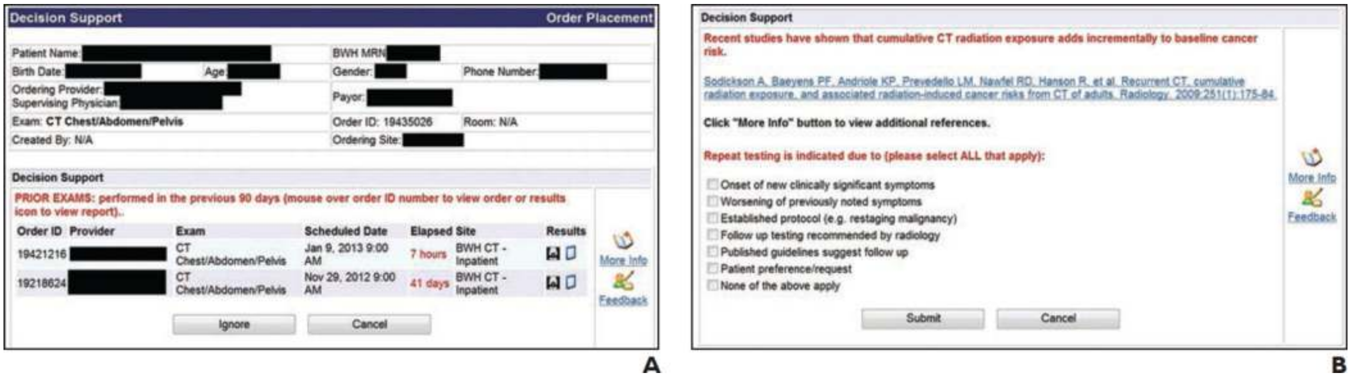

Fig. 1.

Repeat imaging clinical decision support alert system.

A, Alert screen did not require justification to override in preintervention group.

B, After intervention, addition of this screen required orderers to select justification from predetermined menu to override alert and complete order for repeat CT.

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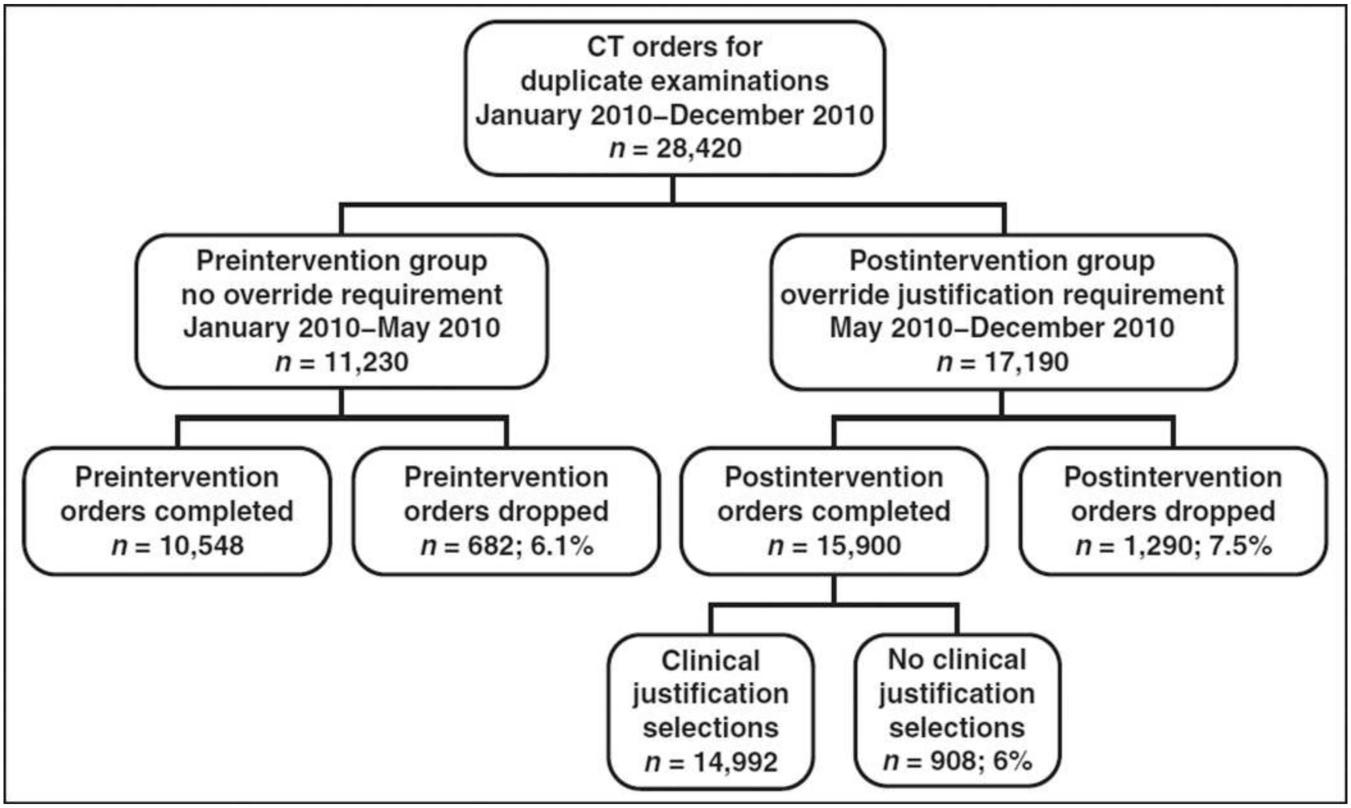

Fig. 2.

Flowchart shows study cohort and disposition. Because of programming errors, justification selections were not collected on 908 orders.

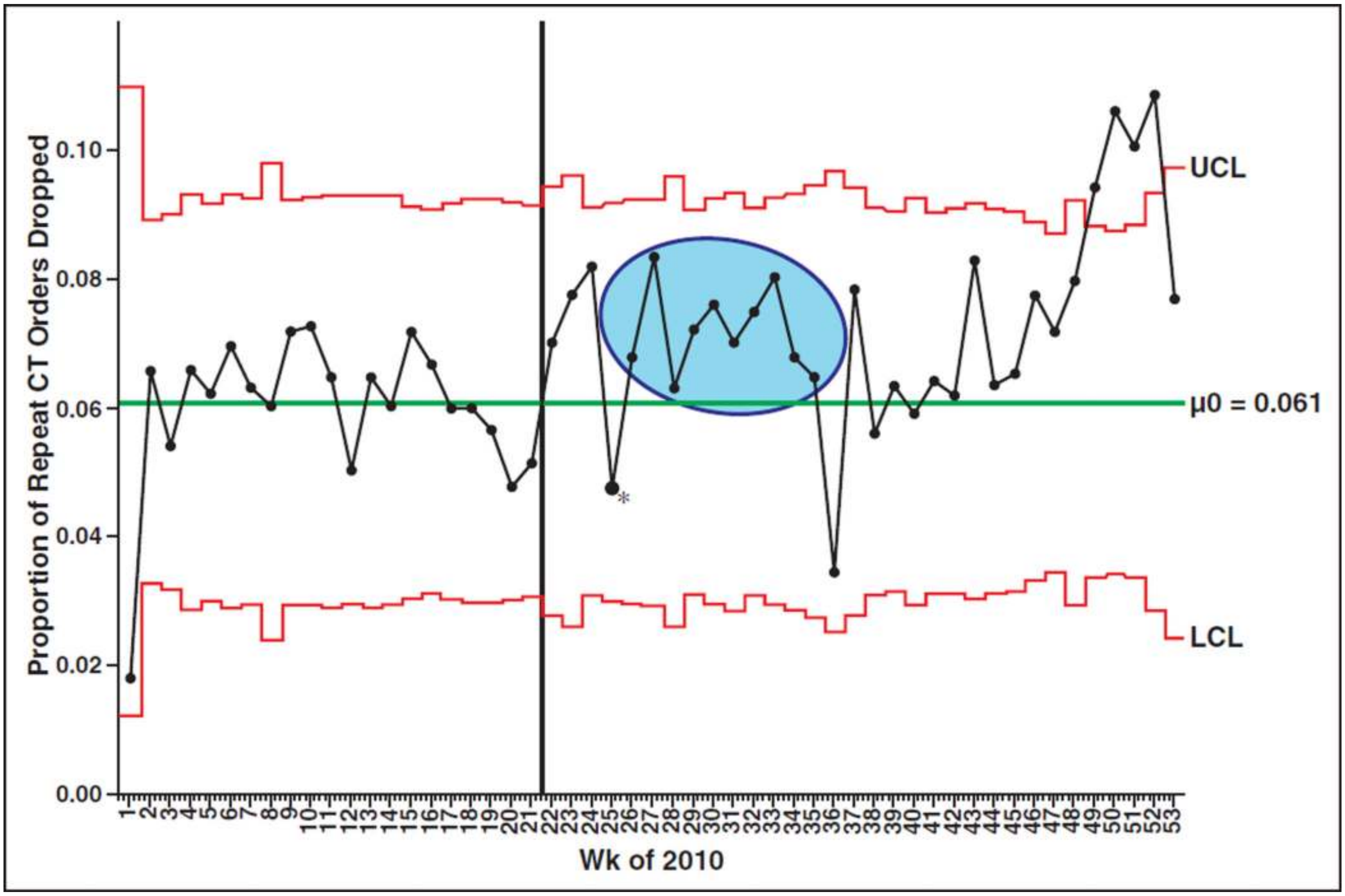

Fig. 3.

Statistical control chart of p-subtype. Intervention occurred at 21.5 weeks (*vertical line*); 6.1% of repeat CT orders were dropped on average at baseline (μ0, *green line*), and degree of common cause (nonsignificant) variation depended on number of repeat CT orders begun each week. Red lines indicate 3 SDs above (UCL = upper control limit) or below (LCL = lower control limit) mean. Repeat CT order drop rate increased immediately after intervention, but run did not become significant due to low drop rate during week 25, first week of new academic year (*asterisk*). Data indicating statistically significant shift (*circle*) began next week, week 26.

TABLE 1

Order Status for Pre- and Postintervention Groups by Care Setting and Orderer Role (n = 28,420 Orders)

Parameter	Dropped Orders: Preintervention %	Preintervention No./Total	Postintervention %	Postintervention No./Total	Absolute Difference (Effect Size) (%)[a]	*p*
Care setting						
Emergency department	7.5	48/641	12.6	164/1301	5.1 (68.3)	**0.001**
Authorized provider		48/622		164/1267		
Nonauthorized provider		0/19		0/33		
Support staff		0/0		0/1		
Primary care	18.6	21/113	26.6	47/177	8.0 (42.9)	0.172
Authorized provider		16/91		41/158		
Nonauthorized provider		0/2		0/1		
Support staff		5/20		6/18		
Specialty	7.6	199/2615	9.3	301/3254	1.6 (21.6)	**0.032**
Authorized provider		15/201		36/309		
Nonauthorized provider		14/77		26/113		
Support staff		170/2337		239/2832		
Cancer center	4.7	244/5177	5.6	442/7913	0.9 (18.5)	**0.033**
Authorized provider		61/2225		135/3453		
Nonauthorized provider		71/1048		125/1661		
Support staff		112/1904		182/2799		
Inpatient	6.3	170/2684	7.4	336/4545	1.1 (16.7)	0.100
Authorized provider		169/2684		326/4440		
Nonauthorized provider		0/40		5/86		
Support staff		1/5		5/19		
Orderer role						
Authorized provider	5.3	309/5778	7.3	702/9627	1.9 (36.4)	**0.000**
Nonauthorized provider	7.2	85/1186	8.2	156/1894	1.0 (25.5)	0.302
Support staff	6.8	288/4266	7.6	432/5669	0.9 (22.7)	0.111

Note—Values for $p < 0.05$ were considered statistically significant and are in **bold**.

[a]Absolute difference is the difference between the proportion of repeat CT orders dropped during the postintervention period and the proportion dropped during the preintervention period. Effect size, or relative change, is this difference divided by the proportion of repeat CT orders dropped during the preintervention period.

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TABLE 2

Predictors of Dropped Orders Using Multivariate Regression Analysis (n = 28,420 Orders)

	Odds Ratio		
Predictor	**Full Model**	**Final Model**	***p***
Override justification requirement present (reference = absent)	1.26 (1.14–1.39)	1.26 (1.14–1.39)	**< 0.0001**
Care setting (reference = cancer center)			**< 0.0001**
Primary care	6.87 (5.11–9.15)	6.87 (5.11–9.15)	**< 0.0001**
Emergency	2.80 (2.32–3.35)	2.80 (2.32–3.36)	**< 0.0001**
Inpatient	1.74 (1.51–2.02)	1.74 (1.51–2.02)	**< 0.0001**
Specialty	1.63 (1.42–1.88)	1.63 (1.42–1.87)	**< 0.0001**
Orderer role (reference = authorized provider)			**< 0.0001**
Nonauthorized provider	1.82 (1.54–2.16)	1.82 (1.54–2.16)	**< 0.0001**
Support staff	1.39 (1.19–1.62)	1.39 (1.19–1.62)	**< 0.0001**
Patient age	1.00 per y	NA	0.719
Patient sex (reference = male)	1.00 (0.91–1.10)	NA	0.961

Note—Full model indicates multiple logistic regression model with all variables. Final model indicates full model with patient age and sex removed (NA). Data in parentheses are 95% CI. Values for $p < 0.05$ were considered statistically significant and are in **bold**.

TABLE 3

Distribution of Justifications for Repeat Imaging, by Orderer Role (n = 14,992 Orders)

Justification	Authorized Provider		Nonauthorized Provider		Support Staff		Total	
	No.	%	No.	%	No.	%	No.	%
Established protocol (e.g., restaging malignancy)	2810	34.7	1140	66.4	3160	61.0	7110	47.4
Onset of new clinically significant symptoms	2248	27.8	187	10.9	125	2.4	2560	17.1
Worsening of previously noted symptoms	1240	15.3	162	9.4	123	2.4	1525	10.2
Follow-up testing recommended by radiology	726	8.1	70	4.1	246	4.8	1042	7.0
Published guidelines suggest follow-up	456	5.6	77	4.5	247	4.8	780	5.2
Patient preference or request	55	0.7	4	0.2	18	0.3	77	0.5
None of the above apply	1308	16.2	178	10.4	1342	25.9	2828	18.9

Note—Orderers were instructed to select all applicable justifications (one or more selections per order). "None of the above apply" was an acceptable justification selection.