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ORIGINAL ARTICLE

The impact of introducing a no oral contrast abdominopelvic CT examination (NOCAPE) pathway on radiology turn around times, emergency department length of stay, and patient safety

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Abstract This investigation evaluates the impact of the no oral contrast abdominopelvic CT examination (NOCAPE) on radiology turn around time (TAT), emergency department (ED) length of stay (LOS), and patient safety metrics. During a 12-month period at two urban teaching hospitals, 6,409 ED abdominopelvic (AP) CTs were performed to evaluate acute abdominal pain. NOCAPE represented 70.9 % of all ED AP CT examinations with intravenous contrast. Data collection included patient demographics, use of intravenous (IV) and/or oral contrast, order to complete and order to final interpretation TAT, ED LOS, admission, recall and bounce back rates, and comparison and characterization of impressions. The NOCAPE pathway reduced median order to complete TAT by 32 min (22.9 %) compared to IV and oral contrast AP CT examinations (traditional pathway) ($P<0.001$). Median order to final TAT was 2.9 h in NOCAPE patients and 3.5 h in the traditional pathway, a 36-min (17.1 %) reduction ($P<0.001$). Overall, the NOCAPE pathway reduced ED LOS by a median of 43 min (8.8 %) compared to the traditional pathway (8.2 vs 7.5 h) ($P=0.003$). Recall and bounce back rates were 3.2 %, and only one patient had change in impression after oral contrast CT was repeated. The NOCAPE pathway is associated with decreased radiology TAT and ED LOS metrics. The authors suggest that NOCAPE implementation in the ED setting is safe and positively impacts both radiology and emergency medicine workflow.

Keywords Abdominopelvic computed tomography · Enteric contrast · Turn around time · Length of stay · Patient safety · Emergency department · Abdominal pain

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Introduction

Abdominopelvic CT examinations are performed with intravenous (IV) and oral contrast to optimize detection or exclusion of pathology and to decrease unnecessary hospital admissions [1–6]. A growing body of literature demonstrates comparable IV contrast-enhanced CT detection rates of pathology among emergency department (ED) patients with or without oral contrast presenting with signs and symptoms of acute abdominal pain [6–20]. Emergency radiologists, emergent care providers, and surgeons are currently debating the optimal imaging protocols for patients in the acute care setting who present with abdominal pain. This discussion entails the competing goals of workflow pressures (patient throughput, overcrowding, improving patient satisfaction) with patient and provider demand to know pathology with certainty. Questions relating to the added value of oral contrast remain [4, 7–10, 13–19, 21].

Several factors have led to examining the need for oral contrast in abdominopelvic CTs among ED patients with abdominal pain. Historically, ED patients with abdominal pain undergoing abdominopelvic (AP) CT examinations drank between 1,000 and 1,500 ml of oral contrast over 2 h [5, 22]. This time has shortened in adults to 45 min to 1 h today. However, the time to complete this process is affected by the time to place the order, the time the nurse or technologist takes

from his/her tasks to give the patient the contrast, the time it takes the patient to drink the contrast, and the time it takes the contrast to opacify the bowel [4, 5, 8, 10, 21–24]. Normal small bowel transit time ranges from 1 to 4 h [25]; incomplete opacification of the bowel in some patients is expected.

Additionally, the evolution of multidetector CT technology provides increased spatial resolution, greater anatomic detail, and reduced motion artifact due to decreased image acquisition time. Volumetric reformatting in coronal and sagittal planes allows the interpreter more ways to view the bowel and may preclude the need for enteric contrast. Enteric contrast was originally administered to help the radiologist differentiate the intraenteric versus extraenteric anatomy and detect bowel pathology. Using the resolution of current MDCTs, patient's own enteric fluids can serve as a negative contrast agent [7, 8, 10, 13, 17].

This observational investigation evaluates the impact of the no oral contrast abdominopelvic examination (NOCAPE) pathway on radiology turn around time (TAT), ED length of stay (LOS), and patient safety. The main goal of this imaging protocol is to decrease the time it takes for patients with abdominal pain to receive a CT examination of the abdomen and pelvis with reliable results.

Methods

Study population

During a 12-month period, we identified all patients that underwent ED AP CT examinations performed for the evaluation of abdominal pain from the institutional clinical data warehouse (CDW) and categorized the examinations based on type of contrast used. We recorded initial AP CT examinations that were performed in the ED. Subsequent AP CT examinations (if necessary) were performed in ED, inpatient or outpatient settings.

The inclusion criteria for NOCAPE protocol were patients, aged 18 and older, who presented to the ED with abdominal pain and were candidates for a traditional CT examination with IV and oral contrast.

The exclusion criteria were patients with recent (within 2 weeks) gastrointestinal surgery or a clinical concern for abdominal fistulae or abscess. These patients underwent AP CT examination with both IV and oral contrast (traditional pathway). Patients were excluded if renal function or allergies precluded IV contrast administration. If the clinical concern was urinary system calculi, neither oral nor IV contrast was administered. Pregnant patients did not undergo any type of AP CT examination.

NOCAPE protocol

The study design was reviewed and exempted by the local IRB as a quality improvement project aiming for best practices for all patients. No investigational interventions were performed on any patient. We implemented the NOCAPE protocol in the EDs of two university-affiliated, urban hospitals in May 2012. Hospital 1 is a community-based hospital with 60,000 annual ED visits, ED admission rate of 25 %, and with its CT scanners in close proximity to the ED. Hospital 2 is a tertiary care center with 35,000 annual ED visits, ED admission rate of 35 %, and a CT scanner with a significant distance from the ED. The CT scanners available in these two hospitals are GE LightSpeed VCT 64-detector row, Siemens Somatom Definition Flash dual-source CT, and GE LightSpeed RT-16. Technologists were aware of the NOCAPE protocol but not the ongoing study measuring TAT. Emergency radiology (ER) staff was aware of the standardized protocol implementation but not protocol cases. The ER staff independently interpreted the exams or reviewed and approved resident's interpretations. The data associated with the NOCAPE protocol was collected for 12 months.

Data collection

During the 12 months, we collected data that included patient demographics, use of IV and/or oral contrast, imaging order to examination completion and imaging order to final interpretation TAT, ED LOS, compliance, popularity and safety metrics including recall and bounce back rates, and comparison of CT examination impressions. Both EDs, all ICU and non-ICU units and outpatient encounters at these two hospitals, share a common electronic medical record (EMR) (Healthcare Information and Management System Society Stage 6 certified electronic medical records, Power-Chart, Cerner). Orders, diagnoses, and imaging interpretations all exist fully within the EMR as discrete data elements that include a date and time stamp for each entry. EMR data flow each night into the CDW, an application that contains patient-level care data for all related hospitals.

Each month, analysts extracted the data for ED patients who underwent AP CT examinations from the CDW and produced hospital-specific reports. They created twelve monthly reports containing the number of patients in each pathway, ED LOS, and median radiology TAT (both the times from order to examination completion and completion to result signature). The investigators had monthly multidisciplinary meetings with analysts, emergency medicine physicians, and surgeons to assure protocol implementation and quality of the data.

Based on the information from the CDW data and monthly reports, we identified, tracked, and analyzed recall and bounce back patients. We defined a recall as a patient who received a second AP CT examination in the ED, inpatient, or outpatient setting within 24 h of the initial NOCAPE CT examination and a bounce back as a patient who received a second AP CT examination in the ED, inpatient, or outpatient setting between 24 h and 14 days of the initial NOCAPE CT examination. We reviewed the clinical characteristics of recall and bounce back

patients including timing and location of second CT examination (ED, inpatient, outpatient), whether the patient underwent abdominal surgery between two examinations and whether there was a change in CT report impression between first and second CT examinations.

Compliance with NOCAPE

We monitored utilization of and compliance with the NOCAPE pathway throughout the study. We defined compliance as the percentage of all ED IV contrast AP CT examinations completed on the NOCAPE pathway. Based on the inclusion/exclusion criteria, we established a 75 % compliance goal throughout the investigation period. We defined "popularity" as the percentage of all ED AP CT examinations (with or without IV contrast, with or without oral contrast) completed on the NOCAPE pathway.

Clinical endpoints

The primary study outcomes included the following: the total number of NOCAPE (with IV contrast, without oral contrast) and traditional (with both IV and oral contrasts) examinations, utilization of NOCAPE examination in the ED. Patient safety was assessed by evaluating recall and bounce back data for patients who underwent the NOCAPE examination. We monitored whether the second AP CT examination occurred in the ED, inpatient, or outpatient setting. Additionally, we monitored the use of IV and/or oral contrast in the second AP CTexamination. Last, we monitored changes in radiologist report impression between the first and second AP CT examinations.

Secondary outcomes included imaging order to complete TAT, imaging order to final interpretation TAT, and ED LOS.

Statistical analysis

Continuous variables were summarized as mean±standard deviation (SD). Categorical variables were expressed as frequency and percentage. Continuous variables with near-normal distribution were compared using Student's independent *t* test, and categorical data were compared using the χ^2 test. All statistical analyses were performed with Stata, Release 10.1 (College Station, TX, StataCorp LP). *P* values <0.05 were considered statistically significant.

Results

Study population characteristics

Table 1 describes patient demographics for each hospital and both hospitals combined. During the study period, a total of 6,409 AP CT examinations were performed in the EDs of these two hospitals. A total of 2,668 ED AP CT examinations were completed on the NOCAPE protocol and 1,096 ED AP CT examinations completed with both IV and oral contrast (traditional pathway) (Fig. 1). NOCAPE examinations represented 70.9 % of all ED AP CT examinations with IV contrast over the 12 months. Mean age of the patients in the NOCAPE group was 49.8 (±18.8) and 48.7 (±18.5) years for traditional pathway (P=0.07). A total of 60.5 % of patients were female in NOCAPE group and 61.5 % in traditional group (P=0.62).

Clinical endpoints: TAT and ED LOS

Median order to examination complete TAT for both hospitals was 1.82 (±0.1) h for NOCAPE pathway and 2.36 (±0.2) h for traditional pathway (P<0.001). This represents 23 % overall decrease for NOCAPE studies. NOCAPE pathway median order to examination complete TAT was 1.84 (±0.1) and 1.78 (±0.2) h for hospitals 1 and 2, which shows 35- (24 %) and 30-min (22 %) decrease in order to complete TAT, respectively (Table 1).

Median order to final interpretation TAT for NOCAPE and traditional pathway was 2.9 (±0.2) and 3.5 (±0.4) h, respectively (P<0.001). This represents 17 % overall decrease for NOCAPE studies. NOCAPE pathway median order to final interpretation TAT was 2.93 (±0.2) and 2.98 (±0.3) h for hospitals 1 and 2, which shows 29- (14 %) and 44-min (20 %) decrease in order to final TAT in each hospital (Table 1).

Last, there was 43-min overall difference in favor of NOCAPE pathway for ED LOS (P=0.003). This represents 9 % decrease in the total time patient spent in the ER. Median ED LOS for NOCAPE studies was 7.48 (±0.4) h for hospital 1 and 7.46 (±0.3) h for hospital 2 which shows 35- (7 %) and 46-min (9 %) decrease, respectively (Table 1).

Clinical endpoints: patient safety

Recall and bounce back rates were 3.2 % (87/2668), and change in impression rates was 1.1 % (1/87) (Fig. 1 and Table 2). Within 14 days, 87 (10 recalls and 77 bounce backs) patients in the NOCAPE group were reimaged. Among ten recalls, one was requested by the emergency radiologist, and all others were requested by the referring provider. The subsequent AP CT examination was with IV and oral contrast (traditional) in 37/87 or 42.5 % of the patients (Fig. 1). The remaining 50/87 AP CT examinations were either without IV contrast or with IV and without oral contrast. While we were interested in the overall change in impression rates, we were most interested in the question of added value of the oral contrast. We also reviewed when the secondary AP CT examination was performed on the traditional pathway. Chart review demonstrated a change

Table 1 Patient demographics, median length of stay, median turn around times in both hospitals

	IV (+) oral (−) "NOCAPE" CT	IV (+) oral (+) "Traditional" CT	*P* value[a]
Number of patients in hospital 1, *n* (%)	1574 (75.2 %)	520 (24.8 %)	
Number of patients in hospital 2, *n* (%)	1094 (65.5 %)	576 (34.5 %)	
Number of patients in both hospitals, *n* (%)	2668 (70.9 %) (compliance[b])	1096 (29.1 %)	
Age in hospital 1, mean (SD)	49.4 (±18.7)	46.8 (±18.3)	**0.007**
Age in hospital 2, mean (SD)	50.5 (±18.9)	50.3 (±18.5)	0.82
Age in both hospitals, mean (SD)	49.8 (±18.8)	48.7 (±18.5)	0.08
Age in both hospitals, range	8–99	15–97	
Female in hospital 1, *n* (%)	935 (59.4 %)	310 (59.6 %)	0.96
Female in hospital 2, *n* (%)	679 (62.1 %)	364 (63.2 %)	0.72
Female in both hospitals, *n* (%)	1614 (60.5 %)	674 (61.5 %)	0.62
Median LOS in hospital 1 (h), mean (SD)	7.48 (±0.4)	8.06 (±0.7)	**0.03**
Median LOS in hospital 2 (h), mean (SD)	7.46 (±0.3)	8.22 (±0.9)	**0.01**
Median LOS in both hospitals (h), mean (SD)	7.46 (±0.3)	8.18 (±0.7)	**0.003**
Median order to complete TAT in hospital 1 (h), mean (SD)	1.84 (±0.1)	2.43 (±0.4)	**<0.001**
Median order to complete TAT in hospital 2 (h), mean (SD)	1.78 (±0.2)	2.28 (±0.5)	**0.003**
Median order to complete TAT in both hospitals (h), mean (SD)	1.82 (±0.1)	2.36 (±0.2)	**<0.001**
Median order to final TAT in hospital 1 (h), mean (SD)	2.9 (±0.2)	3.4 (±0.4)	**0.002**
Median order to final TAT in hospital 2 (h), mean (SD)	3.0 (±0.3)	3.7 (±0.6)	**<0.001**
Median order to final TAT in both hospitals (h), mean (SD)	2.9 (±0.2)	3.5 (±0.4)	**<0.001**

Bold values are statistically significant

[a] Continuous variables with near-normal distribution were compared using Student's independent *t* test, and categorical data were compared using chi square test. *P* value <0.05 was considered statistically significant

[b] Compliance percentage of all ED IV contrast abdominopelvic CT examinations completed on the NOCAPE pathway

IV intravenous, *NOCAPE* no oral contrast abdominopelvic examination, *n* number, *SD* standard deviation, *LOS* length of stay, *TAT* turn around time

in impression between first (NOCAPE) and second (traditional) AP CT examinations in 1/37 patients. In 28 patients, there was no change in impression. In the remaining 8 of these 37 patients, the AP CT examination was performed after abdominal surgery.

Over the study period, a total of seven patients underwent a traditional examination within 14 days after having a NOCAPE exam in the ED or outpatient setting (Table 2). One of those cases appeared to be assisted by the addition of oral contrast into the second study (second CT was performed 14 h after initial CT). The remaining six cases included a planned follow-up for a fluid collection (at day 11), interval development of a bowel obstruction between studies (at day 6), and four cases with no change in the findings (two bowel obstruction and two enteritis) between the studies (at days 7, 10, 14, and 14).

The single patient with a change in impression was a 40-year-old, HIV-positive male who presented to the ED with generalized abdominal pain. The first AP CT examination with IV contrast and no oral contrast (NOCAPE pathway) was interpreted as possible early appendicitis (Fig. 2a). While in the ED under observation and before 24 h, a second AP CT examination with IV and oral contrast (traditional pathway) was ordered by the surgeons. The second CT examination was interpreted as ascending colitis. The entire appendix filled with oral contrast, and appendicitis was excluded (Fig. 2b). The patient was discharged with medical management.

Discussion

To the best of our knowledge, this is the largest observational study of the differences between oral contrast and no oral contrast in AP CT examinations in ED patients with acute abdominal pain. Our results demonstrate a statistically significant decrease in order to complete TAT (32 min—22.9 %), order to final interpretation TAT (36 min—17.1 %), and ED LOS (43 min—8.8 %) when oral contrast is not used. At the same time, we did not find significantly negative patient outcomes in NOCAPE protocol recall and bounce back patients. Anderson et al. showed similar results in their systematic review of literature in adult population with the diagnosis of appendicitis [7]. They showed that no oral contrast AP CT examinations have higher sensitivity, specificity, and positive and negative predictive values compared to all other AP CT modalities suggesting that a quicker noncontrast CT

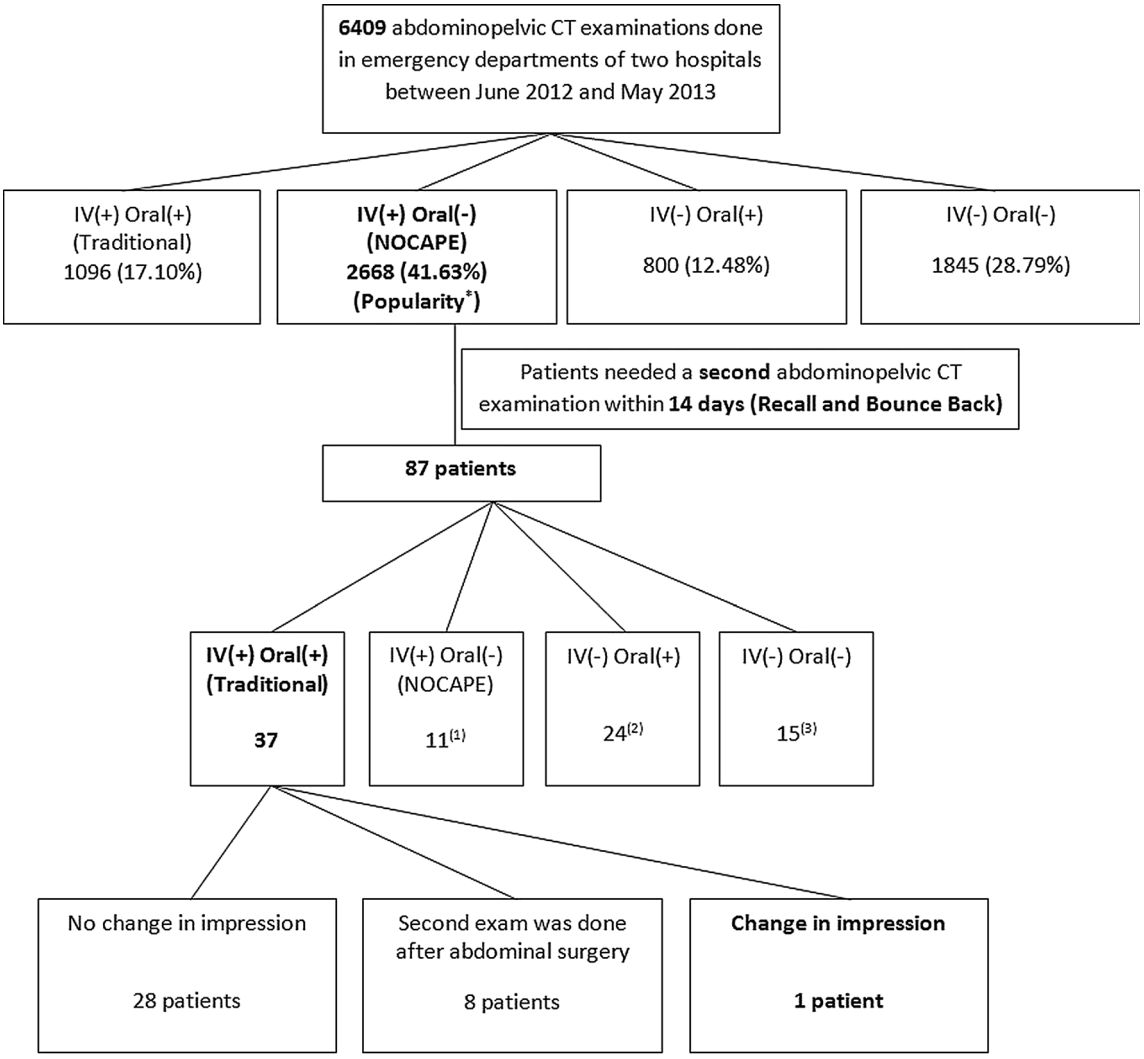

Fig. 1 Study population, recall, and bounce back cases within 14 days

examination in diagnosis of acute appendicitis has similar if not better diagnostic performance than CT examinations with oral contrast. Our investigation expounded on the work of previous investigators as we expanded beyond appendicitis as the sole cause of abdominal pain. We also investigated the difference between these two protocols in terms of ED LOS and radiology department TAT. Our results support improved workflow measures. NOCAPE protocol reduces ED LOS, decreases associated health care costs, and possibly improves patient satisfaction [26–28] with less oral contrast-related patient discomfort (bloating, nausea, and distaste) [11, 22, 29]. The NOCAPE pathway achieved these enhancements without a sacrifice in the quality of care.

Laituri et al. [15] raised the question of how effective the oral contrast is in fully opacifying the small bowel at CT. They reviewed 1,561 children undergoing abdominal CTs for acute abdominal pain that had a 2-h oral preparation. Nearly 30 % of them did not have contrast in the cecum. Further, many patients had nausea/vomiting (19 %), required nasogastric tube (6 %), and had delay in treatment due to the

Table 2 Repeat abdominopelvic CT examinations after no oral contrast CT within 14 days

First CT examination	Second CT examination	Where was the second CT examination?			When was the second CT examination?		Change in Impression?		
		Inpatient	ED	Outpatient	<24 h (recall[a])	>24 h and <14 days (bounce back[b])	Yes	No	Postabdominal surgery
IV (+) oral (−) "NOCAPE" CT examination (*N*=2,668)	IV (+) oral (+)	**30**	**6**	**1**	**1**	**36**	**1**	**28**	**8**
	IV (−) oral (−)	6	9	0	4	11	0	12	3
	IV (+) oral (−)	5	6	0	0	11	0	8	3
	IV (−) oral (+)	21	3	0	5	19	0	22	2
	Total	62	24	1	10	77	1	70	16

Bold values highlights traditional pathway follow-up exams

[a] Recall patients who received a second AP CT examination within 24 h of the initial NOCAPE CT examination

[b] Bounce back patients who received a second AP CT examination between 24 h and 14 days of the initial NOCAPE CT examination

ED emergency department, *NOCAPE* no oral contrast abdominopelvic examination, *IV* intravenous

oral contrast. There was no difference in CT accuracy with or without the oral contrast presence. Standard oral preperation for adult CT patients is shorter (1 hour) than that studied by Laituri in children, suggesting that we may not be adding value with oral contrast in many of those undergoing abdominal CT today.

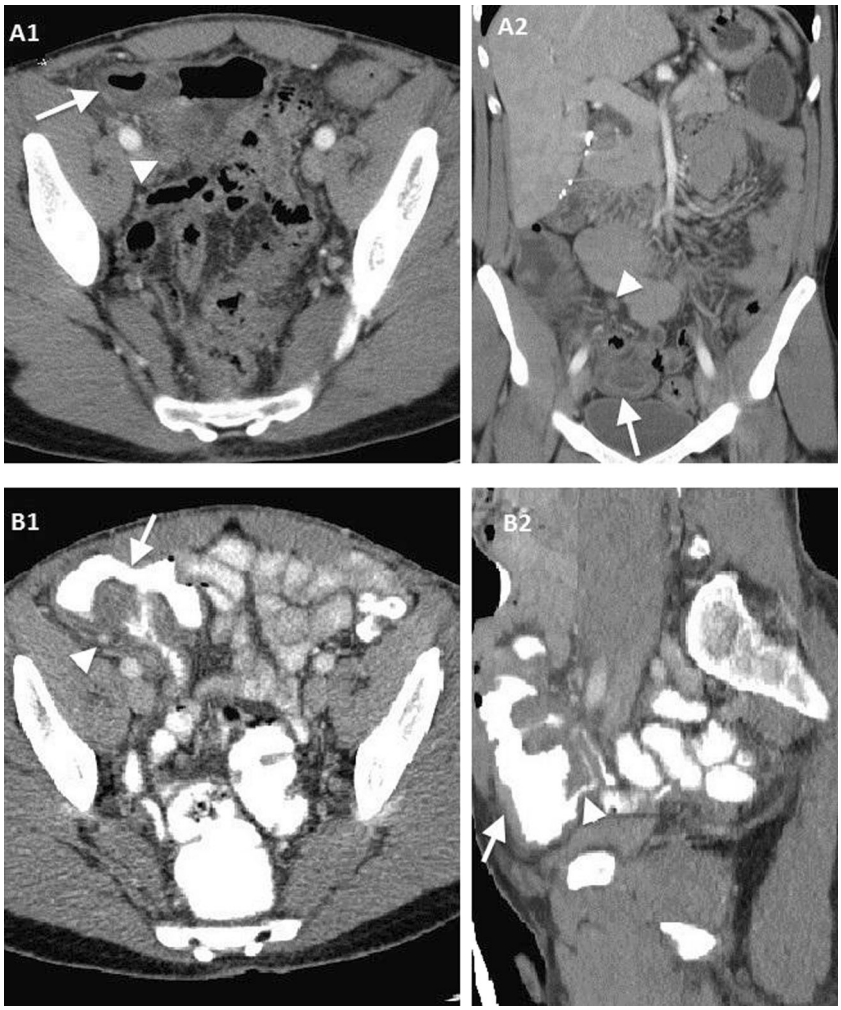

Fig. 2 Abdominopelvic CT examinations of the only case with change in impression. **a1–2** Axial and coronal NOCAPE AP CT. *White arrow head* demonstrates what was interpreted as a prominent appendix. *White arrow* identifies mildly thickened cecum. **b1–2** Axial and coronal traditional AP CT. *White arrow head* demonstrates a normal, contrast-filled appendix. *White arrow* demonstrates thickened cecum

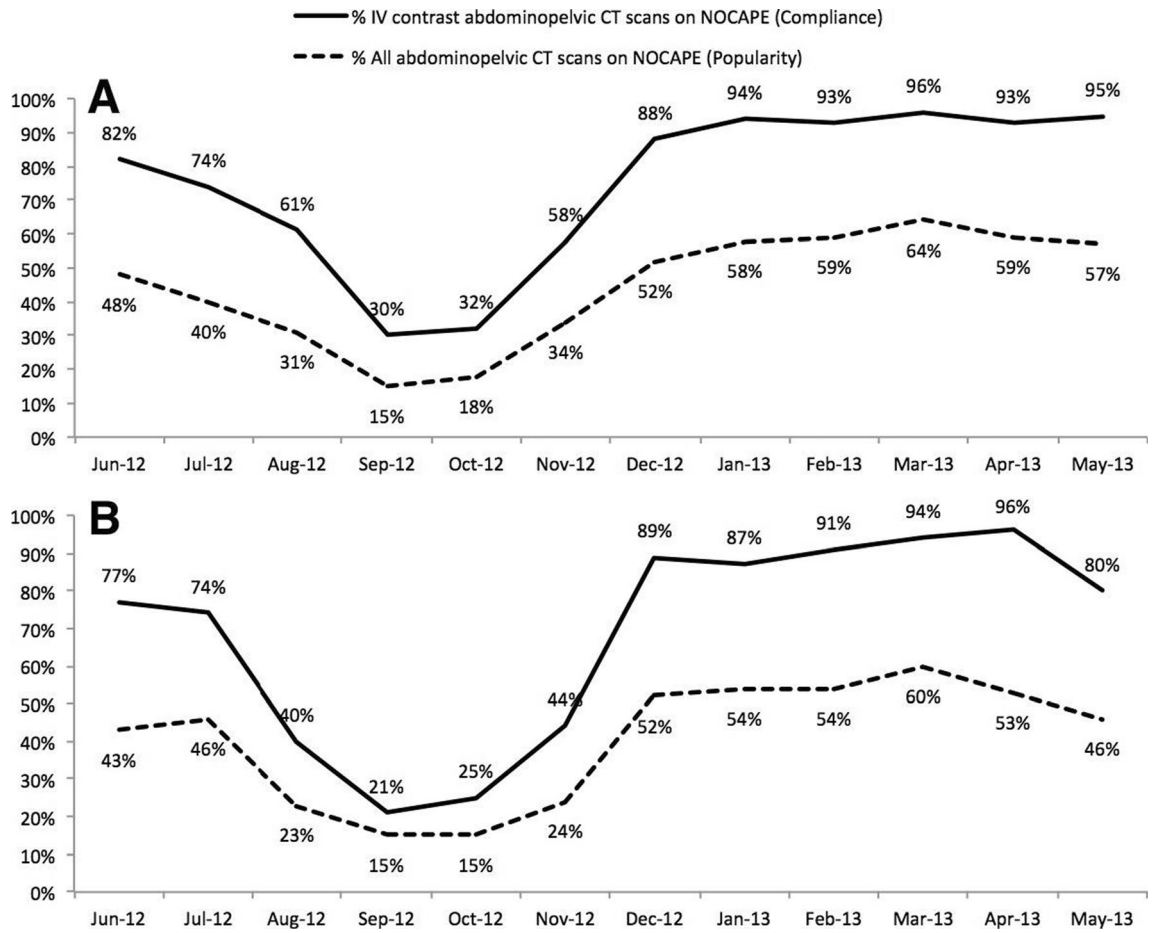

Fig. 3 Compliance and popularity of NOCAPE. **a** Hospital 1. **b** Hospital 2 Compliance percentage of all ED IV contrast abdominopelvic CT examinations completed on the NOCAPE pathway Popularity percentage of all ED AP CT examinations (with or without IV contrast, with or without oral contrast) completed on the NOCAPE pathway

Schuur et al. demonstrated a 30-min decrease in the median ED LOS and a 27-min decrease in median order to complete TAT when performing ED AP CT examinations without oral contrast [20]. These findings are comparable to our combined results for both hospitals. Compared to Schuur and colleagues' study, we also investigated patient safety metrics. We searched and compared a second AP CT examination within 14 days to check for errors and misdiagnoses in the NOCAPE protocol. While the two hospitals in our study are part of a same health care system, the EDs are different entities with different challenges. They do not behave in the same manner in terms of workflow, patient population, patient volume, or distance from radiology to ED. The most prominent difference between the two sites was in ED LOS and order to final TAT. When using the NOCAPE pathway, ED LOS and order to final TAT decreased in hospital 1 by a median of 35 and 29 min. In hospital 2, these metrics were 46 and 44 min, respectively.

Chart review of recall and bounce back patients showed agreement between NOCAPE and traditional pathway CT interpretations in all cases except for one patient. Overall, only 1/2,668 NOCAPE patients had a change in impression. We did not have an adequate number of changes in impression to assess interobserver variation. It is important to note that at academic centers, there are times when residents and fellows make real-time decisions regarding plans of care. This may lead to a concern regarding the skill level to accurately interpret NOCAPE studies to achieve low negative outcomes. Oral contrast might increase the confidence level of radiologists in interpretation. We feel that this is a further area of study, specifically in terms of understanding residents and faculty members' (radiology, emergency medicine, surgery, etc.) ability to make appropriate decisions on NOCAPE studies.

In our investigation, radiology faculty provided both EDs with 24/7 staff coverage. The one case with change in impression occurred during the early months of the investigation. The timing might suggest an adjustment period when moving from interpreting traditional to NOCAPE examinations. While this adjustment may be most pronounced on interpreting physicians (staff/residents), noninterpreting physicians (referring or consulting) may also experience a transition in comfort level.

The overall NOCAPE compliance during the 12-month period was below the 75 % goal. During the second through sixth months, the NOCAPE compliance trended below 75 %. We initially identified this trend after reviewing the report card of the second month. Root cause analysis over a 3-week period identified a problem with the computer physician order entry (CPOE) for the NOCAPE protocol. After identifying the problem, we worked with our information system analysts to correct the problem. Recognition and correction of this IT problem led to improved compliance during the last 6 months of the investigation. The average compliance during the last 6 months versus the first 6 months was 93.3 and 51.5 %, respectively (Fig. 3). During the last 6 months, NOCAPE compliance far exceeded the 75 % threshold.

Limitations

Our study had limitations. Due to radiation safety concerns, we did not perform both NOCAPE and traditional examinations on all our patients. As mentioned, the NOCAPE compliance during the first half of the investigation fell below the intended threshold. The cause was identified and corrected during the second half of the investigation. We could not adequately compare impressions of NOCAPE patients who subsequently underwent abdominal surgery. Comparing CT diagnosis to surgical/pathological diagnosis was beyond the scope of our investigation. We followed NOCAPE patients for 14 days after the initial CT examination. After discussions with radiology, emergency medicine, and general surgery, we reached a consensus of a 14-day bounce back period for patients presenting in the acute care/ED setting. We felt confident that if a clinically significant diagnosis was missed, a patient would represent to the health system within 2 weeks. It is possible that patients with clinically significant diagnoses did not return to the two study hospitals for care that we are unable to account for.

Implications and conclusion

In conclusion, the NOCAPE pathway is associated with decreased radiology TAT, ED LOS, patient risk, and side effects of oral contrast while being associated with favorable patient safety metrics. The authors suggest that NOCAPE implementation in the ED setting positively impacts both radiology and emergency medicine workflow.

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Conflict of interest The authors declare that they have no conflict of interest.

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