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# Implementation of an aortic dissection CT protocol with clinical decision support aimed at decreasing radiation exposure by reducing routine abdominopelvic imaging☆

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ABSTRACT

Patients suspected of having an acute aortic syndrome in the ED typically undergo CT of the chest/abdomen/pelvis. However, the overwhelming majority of these exams are negative. With the help of clinical decision support, we implemented a new radiologist monitored 'aortic dissection screening protocol' that forgoes routine abdominopelvic imaging in order to reduce radiation dose without compromising diagnostic accuracy. The purpose of the present study is to assess the performance of this protocol. A retrospective analysis was performed to study the effect of the dissection screening protocol on the diagnostic yield, radiation and contrast dose on a total of 835 ED patients who underwent CT scans for suspected aortic dissection over a 48-week study period immediately before and after implementation of the protocol. 3.4% (28/835) of examinations were positive for an acute aortic syndrome over the 48-week study period with no difference in positivity before and after implementation of the 'aortic dissection screening' protocol, 3.0% vs. 3.7%, respectively ($p$ = 0.57). There was a 14.6% reduction in median radiation dose and a 16% decrease in contrast volume utilization for the total ED population who underwent CT for aortic dissection using any protocol in the period after implementation of the 'aortic dissection screening' protocol. Aortic dissection CT in the ED is negative in the overwhelming majority of cases. A monitored 'aortic dissection screening' protocol that initially images the chest only significantly reduced contrast and radiation dose without reducing diagnostic accuracy for ED patients who underwent CT for aortic dissection.

## 1. Introduction

Acute aortic dissection is a potentially fatal disease with pre-hospital and in-hospital mortality as high as 20% and 30%, respectively [1]. Unfortunately, aortic dissection is notoriously difficult to diagnose on the basis of history and clinical exam. Furthermore, simple testing, such as electrocardiogram and chest radiography, is almost always non-diagnostic. Multidetector computed tomography (CT) angiography remains the study of choice to diagnose acute aortic syndromes due to its high sensitivity and specificity, rapid acquisition time, and usefulness

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The authors declare that they had full access to all of the data in this study and the authors take complete responsibility for the integrity of the data and the accuracy of the data analysis.

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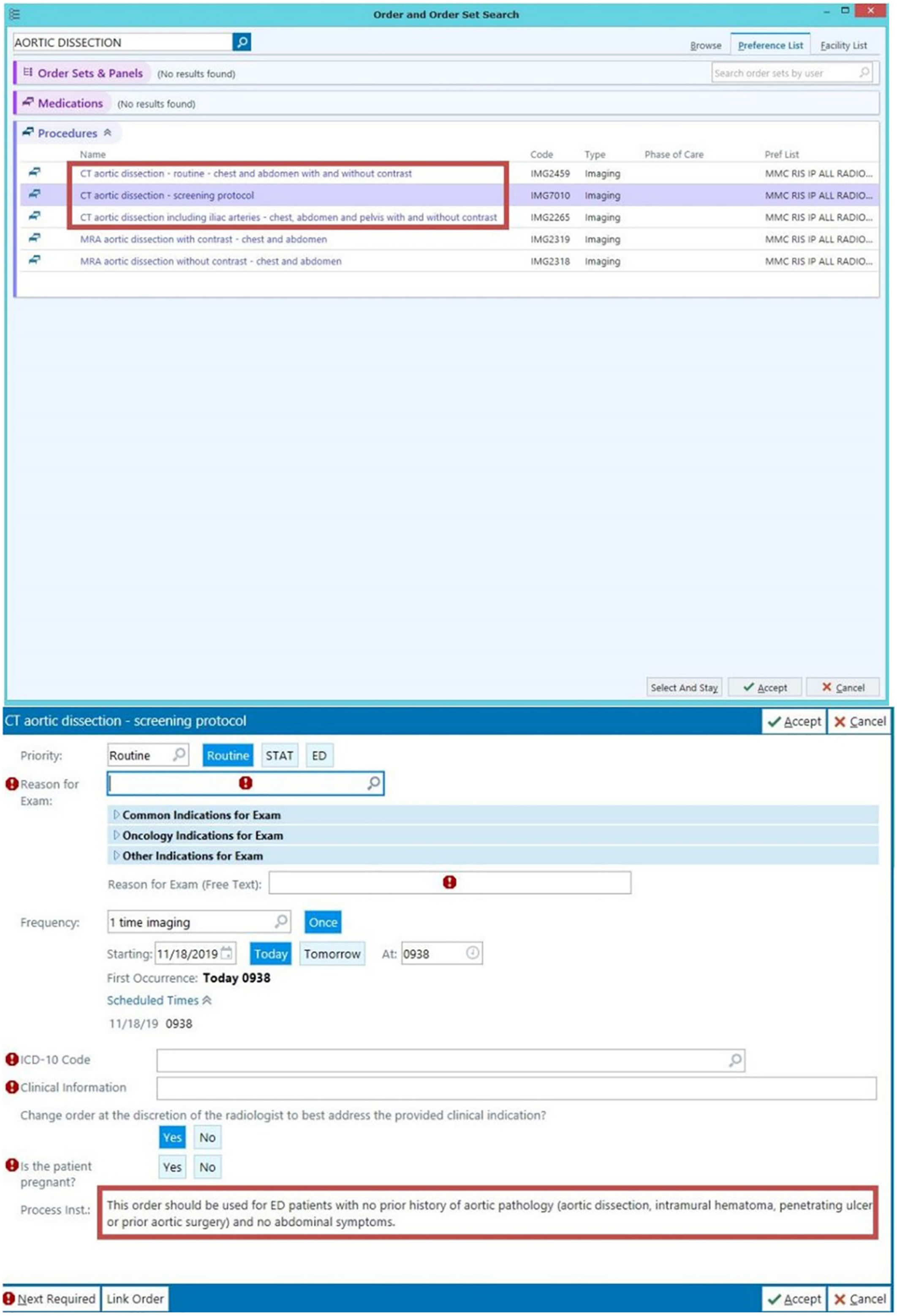


**Fig. 1.** Screenshot of computer provider order entry (CPOE) for CT aortic dissection. Note the process instruction below the clinical information.

for not only diagnosis, but also subsequent treatment planning, particularly in the case of thoracic endovascular aortic repair (TEVAR) [2–5].

The threshold for performing CT is low due to the severity of disease and the persistent lack of effective risk assessment tools. Hence, the yield of CT for an acute aortic syndrome (AAS) including dissection remains low, with a positivity rate of < 5% in a recent series from our institution [6,7]. Additionally, a variety of CT protocols are employed for aortic dissection, ranging from limited anatomic area scanning to including the full iliofemoral vascular anatomy necessary both for full anatomic assessment in cases where dissection extends into the iliac and femoral vessels and for TEVAR procedural planning [8]. Some protocols include pre-contrast, aortic phase and delayed phase imaging, while others include more limited phases. The result is a highly heterogeneous clinical standard of care which leads to some of the highest radiation doses in current CT practice [9]. Striking a balance between the low positivity rate, need for preserving very high sensitivity and desire for wide anatomic coverage on one hand and radiation concerns on the other hand is a significant challenge.

We therefore developed a working group to develop a new CT protocol for Emergency Department (ED) patients suspected of having an AAS that decreases scan coverage, optimizes radiation exposure and controls contrast dose while consistently providing clinically necessary vascular access imaging for positive cases. We implemented a clinical decision tool at CT order entry to assist ED clinicians in choosing the new protocol when appropriate.

The purpose of the present study is to investigate the effect of the new protocol and the associated clinical decision support tool on the diagnostic yield, radiation and contrast dose on ED patients imaged for aortic dissection.

## 2. Materials and methods

### 2.1. Protocol and order development

A multi-disciplinary team, spearheaded by Cardiothoracic Radiology in collaboration with the Emergency Radiology, Vascular Surgery and Emergency Medicine developed a new 'aortic dissection screening' protocol that met the needs of various stakeholders. The emergency department required an easy to order examination with efficient turnaround of results that did not lead to an increase in subsequent imaging. The vascular surgeons stressed a protocol that would promptly and accurately diagnose aortic dissection, while providing the necessary iliofemoral arterial imaging needed for subsequent treatment planning. A protocol that minimized complexity was most important to the CT technologists. For the radiologists, a protocol that minimized radiation and contrast dose, while limiting interruptions to work flow was desirable.

The 'aortic dissection screening' protocol was designed for patients suspected of having an AAS, but who had no history of aortic disease and no abdominal or pelvic symptoms. The protocol used initial CT imaging of only the chest, forgoing routine abdominopelvic imaging. Chest imaging review by a monitoring radiologist, performed while the patient remained on the scanner table, was required to determine whether the study was positive or negative for aortic pathology. A negative CT chest result triggered termination of the examination. A positive CT chest for aortic pathology trigged immediate CTA of the abdomen and pelvis through the common femoral arteries. A monitoring radiologist is available 24/7 at our institution.

Careful stepwise planning was performed to enhance the successful implementation of the newly developed 'aortic dissection screening' protocol. Initially, a memo describing the protocol and its goals was widely disseminated to Radiology technologists and physicians and our colleagues in Emergency Medicine and Vascular Surgery, describing the goals of the protocol and eliciting feedback. Subsequently, a pilot period of 1 month was initiated with the protocol available at one of our three major ED sites. The need for clinical decision support became evident during this period and was developed collaboratively by Radiology, IT and ED (Fig. 1).

The computer provider order entry (CPOE) page for aortic dissection examinations was re-designed to provide clinical decision support in the form of process instructions by steering clinicians to the most appropriate of 3 aortic dissection CT orders based on the suitable situation and population. A simple phrase "This order should be used for ED patients with no prior history of aortic pathology … and no abdominal symptom" was added for further clarity (Fig. 1). There were no explicit questions that permitted or restricted access to any protocol.

After confirming safety and feasibility from key stakeholders, the 'aortic dissection screening' protocol became broadly available for ED patients at our urban academic medical center.

### 2.2. CT acquisition

All CT scans were performed using a 64-detector GE LightSpeed VCT scanner (GE HealthCare, Milwaukee, WI). The tube voltage was chosen based on patient size (100 or 120kVp). The tube current varied as dose modulation was performed. CT axial images with 1.25 mm-thick axial contiguous reconstructions, and sagittal and coronal CT images were archived on PACS. The screening protocol involved pre- and post-contrast, 75 mL IV Isovue 370, (iopamidol, BristolMyer Squibb) CTA of the chest with administration of an additional 75 mL of IV Isovue 370 for abdominopelvic CTA, when required. Computed tomography dose index (CTDIvol) and dose-length product (DLP) were automatically calculated for each study.

### 2.3. Study population

A retrospective analysis of all ED patients who underwent CT for aortic dissection, using any clinically available protocol, was performed for the 24-week time period before and the 24-week time period after implementation of the 'aortic dissection screening' protocol, August 27, 2017 through July 30, 2018.

CT indication, results of the exam, and the anatomic extent of imaging were collected for the first (index) scan for each patient during the study period. The results were classified as positive or negative for acute aortic syndrome. Contrast volume (mL) and radiation dose (dose length product, DLP) were recorded. Additionally, we tallied utilization of follow-up abdominopelvic imaging within 30-days after the aortic dissection CT using Looking Glass™ Clinical Analytics (Streamline Health).

This retrospective study was approved by our institutional review board and is HIPAA compliant. Informed consent was waived.

### 2.4. Statistical analysis

Mean and median contrast volume and radiation dose were compared using the Student's *t*-test and Mann-Whitney *U* test, respectively for the time period before and after implementation of the 'aortic dissection screening' protocol. All tests were 2-tailed and performed at $\alpha = 0.05$. Fisher's exact test was used to compare demographics between the two time period groups.

## 3. Results

Over the 48-week study period, a total of 835 patients underwent CT scans for suspected aortic dissection. Before implementation of the 'aortic dissection screening' protocol, 93% (376/404) of patients were imaged with CT scans of the chest and abdomen and 7% (28/404) with CTs of the chest, abdomen, and pelvis. After implementation of the new protocol, 46% (197/431) of patients were imaged using the 'aortic dissection screening' protocol, 43% (188/431) were CT scans of the chest and abdomen and 10% (46/431) CT scans of the chest, abdomen, and pelvis, (Table 1).

### 3.1. CT results

There were 3.4% (28/835) of examinations positive for an acute aortic syndrome over 48-week study period; 21 aortic dissections (Type A-15, Type B-6), 6 penetrating atherosclerotic ulcers and 1 isolated intramural hematoma. The positivity rate did not differ between the periods before and after implementation of the 'aortic dissection screening' protocol, 3.0% (12/404) vs. 3.7% (16/431), respectively, $p = .57$, Fisher exact.

### 3.2. Radiation dose and contrast volume

The mean dose DLP for the 'aortic dissection screening' protocol CT

**Table 1**
Anatomic scope of CT scans performed for aortic dissection in the Emergency Department patients over the 48-week study period

| | Before screening protocol ($n$ = 404) | After screening protocol ($n$ = 431) | p-Value |
|---|---|---|---|
| Men | 192 (48%) | 186 (43%) | 0.2 |
| Age (years, /SD) | 61.7 ± 15.0 | 61.2 ± 14.9 | 0.3 |
| CT chest and abdomen | 376 (93%) | 188 (43%) | |
| CT chest, abdomen, pelvis | 28 (7%) | 46 (11%) | |
| CT chest screening protocol | Unavailable | 197 (46%) | |
| Positive cases of AAS | 12 (3.0%) | 16 (3.7%) | 0.57 |
| Median and range DLP (mGy*cm) | 477.4 (162.1–2111.3) | 407.8 (102.1–2333.1) | < 0.00001 |
| Mean contrast (mL) | 111.2 ± 13.8 | 93.5 ± 21.9 | < 0.00001 |
| Median and range contrast (mL) | 100 (60–160) | 80 (60–180) | < 0.00001 |
| Total CT exams | 414 | 444 | |

was 389.4 ± 202.0 mGy*cm.

There was a significant, 14.6% reduction in median radiation dose for the total ED population who underwent CT for aortic dissection using any protocol in the period after implementation of the 'aortic dissection screening' protocol. Before implementation the median dose was 477.4 (IQR 162.1-2111.3) mGy*cm, decreasing to 407.8 (IQR 102.1-2333.1) mGy*cm, ($p < 0.00001$) after implementation. This reduction was largely driven by a significant increase in CT scans with a DLP of ≤300 mGy*cm; 78 exams prior to implementation of the 'aortic dissection screening' protocol versus 137 after implementation, ($p < 0.05$, Fisher exact, (Fig. 2).

Contrast volume decreased 16% after implementation of the 'aortic dissection screening' protocol to a mean of 93.5 ± 21.9 mL from 111.2 ± 13.8 mL, $p < 0.00001$.

### 3.3. Follow up abdominopelvic CT imaging

In patients for whom initial aortic dissection CT was negative for acute aortic syndrome, there was no significant difference in follow-up abdominopelvic CT examinations within 30 days after the aortic dissection CT imaging: 5.9% (23/392) before and 7.2% (30/415) after implementation of the 'dissection screening protocol', $p$ = .48.

## 4. Discussion

The present study demonstrates the safety and efficacy of our new 'aortic dissection screening' protocol, implemented with clinical decision support. The protocol, developed in concert with clinical stakeholders, served two main functions: reduction of radiation exposure and contrast dose for patients without dissection while ensuring that positive cases have complete vascular imaging for procedural planning. Abdominal imaging was obviated for nearly half of the imaged ED population, when we targeted those without abdominal symptoms or history of aortic disease for the 'aortic dissection screening' protocol. This builds on our prior work aimed at refining appropriate imaging for ED patients suspected of having an acute aortic syndrome while reducing radiation exposure [6,7].

Khorsani et al. demonstrated that for clinical decision support to be most effective it should be brief, embedded in routine workflow and actionable without vague or evasive language [10,11]. We created our CPOE on this model, aiming to guide the ordering clinician in choosing the most appropriate imaging study in the moment that a requisition was generated. The CPOE had a dramatic impact, evidenced by the high percentage (46%) of studies performed as 'aortic dissection screening' within a short period after availability.

Haji-Momenian et al. retrospectively reviewed the effect of chest only imaging for ED patients who underwent CT of the chest, abdomen and pelvis for aortic injury, using their usual protocol [12]. Their positivity rate was 2.9% with chest involvement in all cases. They proposed that substantial reduction in radiation exposure could be achieved by omitting abdominopelvic imaging, except in positive cases. Our 'aortic dissection screening' protocol was prospectively implemented clinically to leverage the radiation reduction inherent to restricting the anatomic scope of imaging. Our routine dissection protocol previously restricted the scope of imaging to the chest and abdomen, excluding the pelvis, in line with our longstanding radiation reduction program [6,13]. Hence our 15% reduction in median radiation dose to the imaged ED patients builds on these advances, and

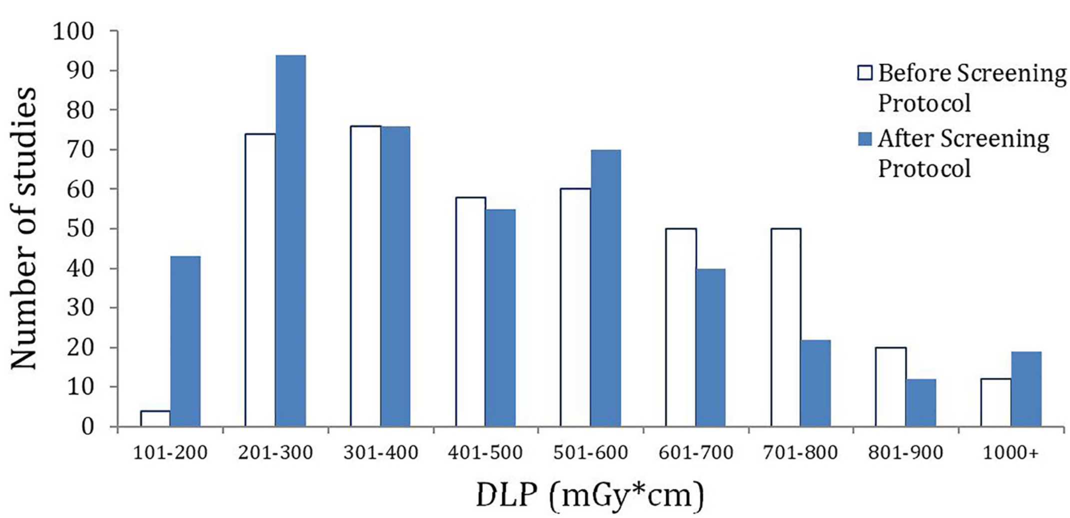


**Fig. 2.** Radiation dose (DLP) for Emergency Department patients who underwent aortic dissection CT before and after implementation of the 'aortic dissection screening' protocol.

although modest, is beneficial at the population level. The slight uptick in pelvic imaging after implementation of the 'aortic dissection screening' protocol is in line with our monitoring of the CT scans, hence ensuring full vascular imaging for positive cases.

Generalizability of this study is limited by the performance of the present study at a single multisite urban academic medical center. Although the process of monitoring 'aortic dissection screening' CT scans required a workflow adjustment, it has been fully adopted into our clinical practice 24/7; this may not be feasible in other practice settings, especially when real time physician monitoring is not available at all hours. Additionally, the three available aortic dissection protocols, including the new 'screening' protocol employed pre-contrast imaging of the chest to increase the conspicuity of intramural hematoma. Dual energy CT with virtual non-contrast images, not available to us during the study period, may obviate the need for this series, resulting in further reductions in radiation exposure. [14–16] After implementation of the 'screening' protocol, we continue to have the CT chest/abdomen protocol remain available primarily because this had been the mainstay protocol for aortic pathology evaluation at our institution. Referring clinicians also viewed this protocol as providing the added benefit of evaluation for solid abdominal organ pathology.

While reducing the number of patients in whom imaging of the abdomen was obtained, we feared that incidental and even clinically relevant findings may be missed as was demonstrated in a recent review of incidental findings on coronary CT examinations. [17] However, there was no significant difference in follow-up abdominopelvic CT examinations within 30 days after the initial aortic dissection CT imaging compared to before the 'screening' protocol. Furthermore, the recent study which evaluated the effect of chest only imaging for 238 ED patients who underwent CT of the chest, abdomen and pelvis showed that no acute abdominal pathology was missed in patients without abdominal symptoms [12].

Given the high imaging rate and low yield for ED patients who undergo CT for aortic dissection, ongoing efforts to safely reduce radiation exposure, while ensuring complete imaging necessary for treatment of positive cases is crucial. Results of the present study suggest that this goal may be achieved with the aid of clinical decision support designed with interdisciplinary collaboration.

## Declaration of competing interest

1. Vishal Patel - Declarations of interest: none
2. Alana Fruauff - Declarations of interest: none
3. David Esses - Declarations of interest: none
4. Evan Lipsitz - Receives research Support from Cook, Inc., paid directly to Montefiore Medical Center. Otherwise no personal disclosures.
5. Jeffrey Levsky - GE healthcare paid for travel funds for department
6. Linda Haramati - Declarations of interest: none


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