Improving the Quality of CT Pulmonary Angiograms using Lean Six Sigma Methodology

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Introduction

A CT pulmonary angiogram (CTPA) ordered for the evaluation of pulmonary embolus (PE) may be deemed a suboptimal study by the reading radiologist due to contrast bolus and/or artifactual problems. When this occurs, evaluation of the pulmonary arterial system to the level of the subsegmental branches is not possible, and a repeat CTPA or a Ventilation/Perfusion (V/Q) scan is often recommended. All CTPA studies at the James A. Haley Veterans' Hospital were reviewed from January 1, 2018 through April 30, 2019, and 1684 studies had been performed. Studies not clearly optimal or suboptimal due to variations in reporting techniques were excluded from performance analysis.

Problem Statement

CTPA studies during this 16-month period were definitively suboptimal 32.5% of the time (460/1415), with a suboptimal contrast bolus in 24.0% of included studies (336/1402). In comparison, average hospital rates nationally according to published literature are 4-10% for all causes, and 2-5% for bolus timing.[3,6] The performance of other VA sites statewide were analyzed via 100-study samples, with the best suboptimal bolus rates of 5-6%.

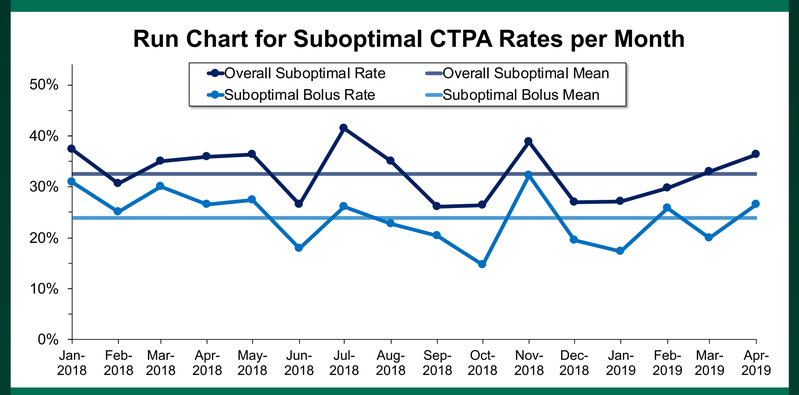

Figure 1. Baseline suboptimal bolus and overall/all-cause suboptimal (including bolus and/or artifact documented to have affected the evaluation of the pulmonary arterial tree) study rates at this center.

The downstream effect of suboptimal and nondiagnostic studies impacts patient safety. In a 6-month subset where suboptimal and ambiguous cases were included (n = 258), 33 patients were started on therapeutic dose anticoagulation afterwards, with three suffering clinically significant bleeding. Furthermore, 7 patients underwent repeat CTPAs, 7 underwent V/Q scans, 8 underwent non-invasive vascular imaging as a surrogate test, and 2 underwent echocardiography as a surrogate test.

Project Goals

- Primarily to decrease the overall suboptimal CTPA rate at this hospital by 50% or more within 6 months.
- Multiple Plan-Do-Study-Act (PDSA) cycles will be employed and if this goal is achieved in advance, the team will continue implementing improvements with a secondary goal of meeting the suboptimal CTPA rates seen in the national literature.

Analysis

A multidisciplinary team was created across the Medical and Radiology services. The DMAIC (Define, Measure, Analyze, Improve, Control) framework was utilized throughout the project. This facility's process was analyzed via Gemba walk (Figure 2). It was then compared to other VA hospitals statewide following telephone surveys. An Ishikawa cause-and-effect diagram was constructed (Figure 3), and possible interventions were analyzed via an Impact-Effort matrix (Figure 4). Decisions on critical root causes, interventions, and dates of implementation were made by committee. Factors relating to contrast bolus timing and quality became the focus and a secondary goal was created to achieve a suboptimal bolus rate of 10% or less.

On May 1, 2019, interventions including a contrast injection rate increase on all CTPAs to 5 mL/sec from 4 mL/sec,[2] standardization of bolus reporting, and retraining of CT technologists[1,4,5] were implemented for a 6-week trial period.

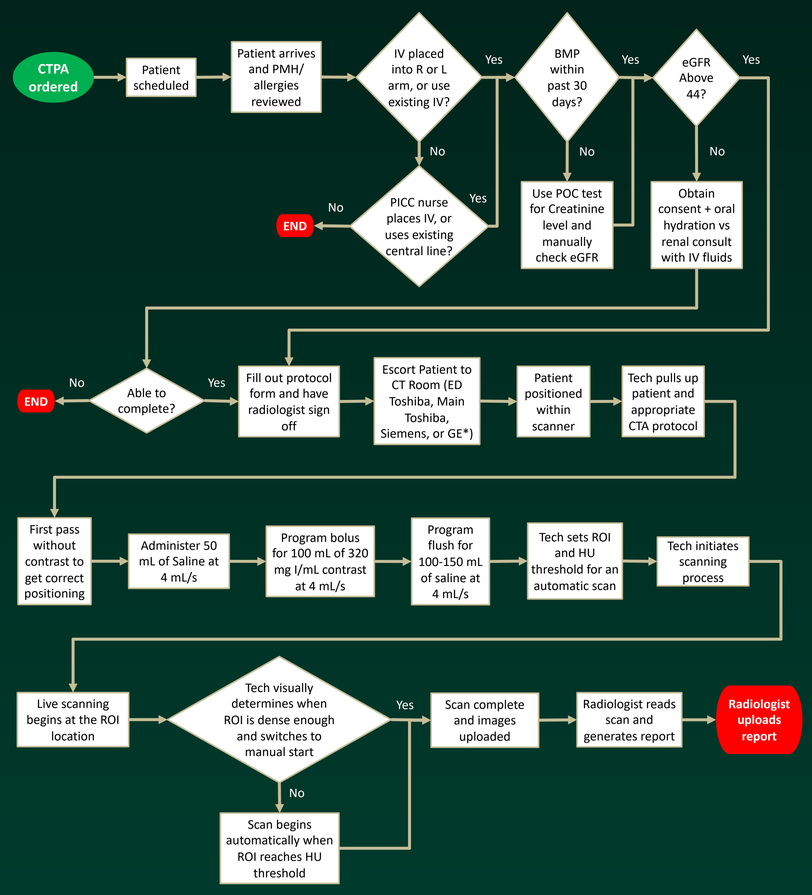

Figure 2. Original current state process map for CT pulmonary angiograms.

PMH = past medical history; PICC = peripherally-inserted central catheter; BMP = basic metabolic panel; POC = point of care; eGFR = estimated glomerular filtration rate; ROI = region of interest; HU = Hounsfield unit

* The GE scanner was phased out prior to the onset of this PDSA cycle due to lack of automaticity

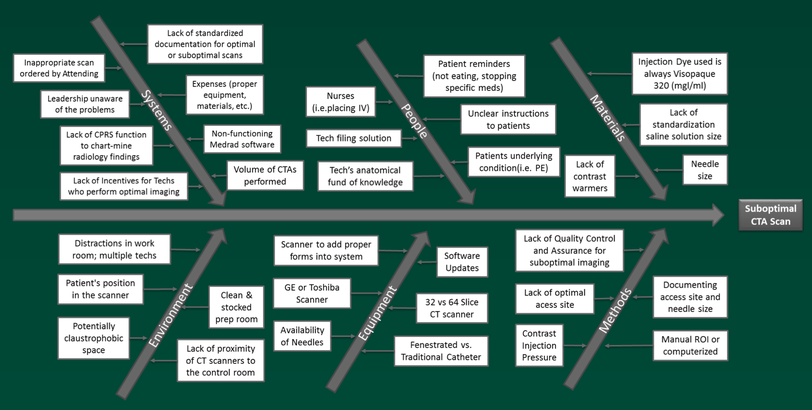

Figure 3. Ishikawa diagram for possible root causes of suboptimal CT pulmonary angiograms. This is also known as a Cause-and-Effect or Fishbone diagram.

CPRS = computerized patient record system; ROI = region of interest

IMPACT \ EFFORT	LOW	HIGH
HIGH	**1. Perform using scanners with automated capabilities only *** **2. Increase the autoinjector rate to 5 mL/s +** **3. Re-train techs on the process, especially ROI placement *+** **4. Hang flyers for ideal placement +**	1. Buy and use 350 mg I/mL contrast # 2. Buy and use contrast warmers, and warming autoinjector sheaths # 3. Buy and use 2 new 256-slice MDCTs with advanced automated features #
LOW	**1. Buy and use fenestrated IV catheters *** **2. Aim for right-sided antecubital IVs *** **3. Improve tech documentation *+** **4. Improve radiologist documentation *+**	1. Integrate BMI into a contrast volume algorithm 2. Integrate ECHO results into a contrast timing algorithm 3. Decrease respiratory motion beyond merely software voice instructions

Figure 4. Impact-Effort Matrix, or a "Pick Chart," to prioritize possible interventions on the critical root causes.

ROI = region of interest; MDCT = multi-detector CT; BMI = body mass index; ECHO = echocardiogram

* attempted previously circa 2015, either successfully or unsuccessfully
+ implemented during this PDSA cycle; altered if previously unsuccessful
# planned for future PDSA cycles

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Outcomes

The suboptimal CTPA rates for May 2019 became the best since data collection began, with an all-cause rate of 25.9% (29/112) and a suboptimal bolus rate of 13.4% (15/112).

Through June 10, 2019, the 6-week trial for this PDSA concluded. It yielded improvements in all-cause suboptimal rates to 24.7% (36/146, p = 0.02) and in suboptimal bolus rates to 12.3% (18/146, p < 0.001).

Sustainment

- Continued monitoring will take place via chart review, data analysis, and retention of regular communication of the interdisciplinary team which includes a champion from the hospital's executive leadership.
- Contrast bolus performance will be plotted weekly on a control chart and checked for special cause variation (Figure 5).

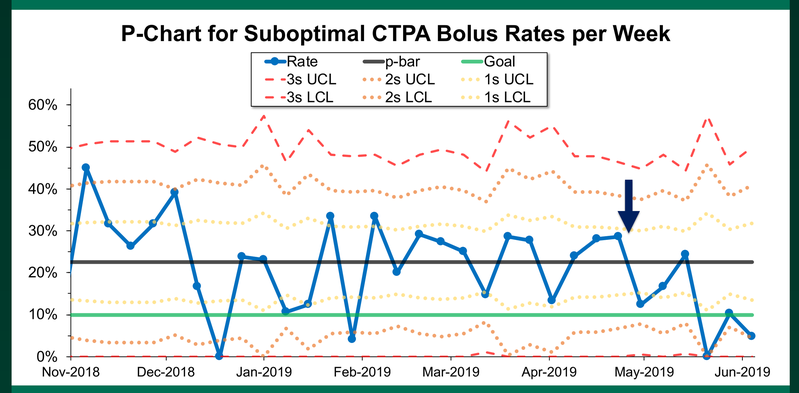

Figure 5. Control chart for suboptimal bolus rates amongst all CTPA studies at this center, including control limits for 1-3 sigma above and below the mean, p-bar. The arrow notes the onset of this 6-week PDSA. The December 2018 decline correlated with a department meeting which discussed root causes and proposed interventions. All points signify common cause variation.

UCL = upper control limit; LCL = lower control limit; s = sigma, or standard deviation

- All cases with a suboptimal bolus incur a deep dive into the possible root cause(s).
- Communication will also include compliance with documenting ROI placement, rate of contrast injection, and IV size and location.
- Protocols and other reference materials were updated accordingly.
- The annual tech competency form was modified to require specific volumes of angiographic studies.
- Use of an internal web-based form is also in place, and encouraged for logging cases that exhibit poor as well as excellent bolus timing.

Future Work

- A subsequent PDSA cycle started on June 11, 2019 to implement use of a higher concentration of iodinated contrast media on all CTPAs to 350 mg I/mL[1,2] from 320 mg I/mL for at least a six-week period. Pending the results, use of this contrast medium may be expanded to all angiographic studies in the facility.
- Following this, if the suboptimal rates are not yet at goal, a PDSA cycle may be pursued in which the 350 mg I/mL will be heated to body temperature in a warming cabinet on all CTPAs.
- Two new, 256-slice CT scanners have been purchased to replace the current 64-slice machines. A future PDSA will analyze the suboptimal CTPA rates following installation of this hardware and the accompanying software package with advanced automated features.

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