Quality Improvement: Reducing Chest Radiographs in the Cardiac Surgery Intensive Care Unit

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A DNP Project Manuscript
Submitted in Partial Fulfillment of the Requirements for the
Doctor of Nursing Practice Degree

University of Maryland School of Nursing
March 2022

Abstract

Problem: Daily chest radiographs (CXRs) are a part of routine care for intensive care unit (ICU) patients. The Choosing Wisely campaign is an evidence-based practice initiative by the American Board of Internal Medicine (ABIM) that promotes providers to rethink unnecessary medical procedures without clinical indication. Obtaining daily CXR in the ICU has proven to be costly, exposes patients to unnecessary radiation, and provides a low yield of clinically significant data.

Purpose: The purpose of the quality improvement project (QI) was to implement an evidence-based decision algorithm to reduce unnecessary daily chest CXRs in ICU patients. The algorithm encouraged CXRs to be ordered on demand for this population when clinically warranted to investigate a clinical concern.

Methods: Following education of unit staff, a decision algorithm was implemented with a practice change bundle if the patient qualified for on-demand CXRs. Pre and post data were collected through chart audits and on data from the Radiology Information System (RIS). Data collected measured staff ICU note adherence to the chest radiograph algorithm, the diagnosis for CXR screening, and the total number of CXR sent in a monthly period.

Results: Data collection took place over 15 weeks including three weeks of baseline data. During the implementation period weekly staff adherence to the decision algorithm increased. The findings suggest increasing practice of ordering on demand CXRs based on eligibility.

Conclusions: Significant outcomes of the project were twofold. First, health care cost reduction was achieved by reducing the cost of unnecessary CXRs. Second, increased patient safety was achieved by reducing the amount of patient radiation exposure related to routine daily CXRs.

Quality Improvement: Reducing Chest Radiographs in the Cardiac Surgery Intensive Care

Daily chest radiographs (CXRs) are a part of routine care for intensive care unit (ICU) patients. Due to an outdated practice, daily CXRs are routinely ordered in the ICU regardless of clinical necessity. Guidelines recommend a shift in practice based on evidence to reduce unnecessary daily CXRs and to order them as needed to workup clinical patient concerns. The Choosing Wisely campaign is an initiative of the American board of Internal Medicine (ABIM) Foundation recommending the ordering of daily CXRs only if there is an indication for workup of a clinical diagnosis (Choosing Wisely, 2014). The campaign guideline stresses that unnecessary CXRs increases health care costs, can cause harm to the patient, and refutes that a clinical finding will be missed with routine CXRs.

In the cardiac surgery intensive care unit (CSICU) at an urban academic medical center, all patients automatically received a routine daily CXR order. Routine morning CXRs were a part of the unit's culture and occurred without discussion or decision to the clinical needs of the patients. The order was carried out by the radiology technician based on the CSICU provider's order for the routine CXRs. Each morning the surgical and medical teams met to discuss the interval patient clinical events of the past 24 hours. The routine morning CXRs were displayed but rarely discussed. Later in the day, during critical care rounds, the CXRs were viewed again during discussion of the pulmonary system. Clinical decisions were rarely made based on the daily morning CXRs. The cardiac surgery intensive care unit at this facility was the only ICU in this hospital that continued to obtain routine morning CXRs. The other ICUs obtained CXRs on demand when there was a clinical change in the patient. The purpose of this quality improvement (QI) project was to change routine daily CXRs orders to on demand ordering by implementing a patient selection decision algorithm on the CSICU to decrease unnecessary CXRs, patient radiation exposure, and health care related costs.

Literature Review

Peer-reviewed journal articles were found to support evidence for this QI project. One Melnyk level of evidence level I, four level three, and one level seven articles were analyzed. The evidence reviewed focused on decreasing CXRs ordered combined with cost savings and decreasing radiation exposure without sacrificing patient safety and missing clinically relevant data. Halpern et al. (2014), who developed the policy statement for the Choosing Wisely Campaign, reported that less than 6% of the 2,457-daily routine CXRs found clinically important data. This finding debunks the concern that clinically significant data will be missed without daily CXRs. After a protocol was created for determining the necessity of a CXR, the incidence of CXRs decreased by 36%.

Prioritizing and identifying clinical indications for CXRs and reduced radiation exposure was determined to be an effective, safe approach and contributed to improved patient safety (Kevenson et al., 2017; Salehi et al., 2017; Tolsma et al., 2015; Trumbo et al., 2019; Wu et al., 2020). Cost savings are another important outcome from reduced daily routine CXRs. In a large study conducted in post operative CSICU patients, Tolsma et al. (2015) reported that the number of routine CXRs were reduced by 73% in one year after implementing a new protocol where routine daily CXRs were replaced exclusively by on demand CXRs with specified clinical indications. This intervention had a cost savings of $40,000 in the one year of implementation of new protocols. When CXRs were ordered on demand, the diagnostic clinical efficacy based on clinicSal workup necessity was 7% as compared to 3% with routinely placed CXRs.

Salehi et al. (2017) compared two groups where one group received routine daily CXRs and the limited CXR group only received one CXR when downgraded out of the ICU unless there was a clinical concern. The clinical efficacy of the limited CXR group was 56% when a CXR was obtained to confirm an abnormality when compared to 14.4% of the routine daily CXR group. Ganapathy et al. (2012) found in their meta-analysis that performing routine daily CXRs can be eliminated without affecting ICU or hospital mortality.

Kevenson et al. (2017) removed the option for daily CXR from their electronic health record-based ordering system and only allowed for a CXR if it was clinically warranted. The average monthly CXR decreased by 64% in the medical ICU and 35% reduction in the surgical ICU, which saved the institution $322,000 to $363,000 in the two years since this new protocol was initiated.

Wu et al. (2020) decreased the total CXRs per patient day by 36.1% and the charges to patients for CXRs decreased by $7,750 per month. Trumbo et al. (2019), were able to decrease CXRs in the Cardiac Surgery ICU with a clinical significance ($p<0.001$) with education and data to support reduction of routine CXRs.

Routine CXRs can be a source of harm to patients via radiation exposure emitting 0.1mSv of radiation (Kevenson et al., 2017). While a single CXR exposure is not high enough to cause damage, it is the risk of unnecessary, cumulative, and repeated exposure of radiation to the patient that becomes problematic. Wu et al. (2020), decreased radiation exposure per census from 0.011 to 0.008 mSv.

The evidence supports to reduce non clinically indicated CXRs to decrease healthcare costs, decrease exposure of radiation, and to obtain only when clinically indicated.

Theoretical Framework

Donabedian's Quality Framework (See figure 1) is a framework assessing the quality of care and linkage to what is under the control of the medical professional and the effect on patient outcomes (Donabedian, 2005). The framework was chosen to help guide the QI project implementation strategies for improved clinical utilization of CXRs. The framework has three parts: (structure, process, outcomes). The health care structure is defined as the physical and organizational aspects of health care settings. This includes the facilities, operational, and financial processes supporting medical care. The process of patient care relates to the structures that provide resources and mechanisms to carry out patient care activities. The outcomes of patient care are related to the status of patients and populations based upon the effects of the structure and process had on their care.

Donabedian's framework supports the practice change in this quality improvement project since care coordination is influenced by the setting and the process of care. The cardiac surgery ICU's setting and unit culture directly affects the patient's safety with increased radiation exposure by obtaining daily morning CXRs. This theoretical framework shows the relationship of how changing parameters of the setting, care delivery, and care coordination will affect health outcomes for that patient.

Helfrich's (Helfrich et al., 2007) conceptual framework (See figure 2) focuses on the organizational level where all staff must share the priority of a specific task in providing the most cost effective and safe care (Helfrich et al., 2007). If morning CXRs are no longer obtained on a routine and daily basis, it is anticipated that fewer CXRs will result in cost reductions and less radiation exposure. The second characteristic of the framework refers to the consistency and quality of implementation effectiveness which relates to the project of implementing evidenced based tactics (Helfrich et al., 2007). In keeping with the framework, a QI project was developed and implemented following best practices and evidence-based practice recommendations.

Methods

The setting for this project was on a 30-bed cardiac surgery intensive care unit (CSICU) in a large, urban academic medical center. The patient population of this unit are adults greater than 18 years old of all genders. No population was excluded based on demographics between September 30, 2021, to December 14, 2021. Patients were excluded from the practice change based on the evidenced based clinical decision tool algorithm based on their type of surgical intervention or invasive devices present.

The evidence-based intervention goal was to implement practice changes that reduced routine daily CXRs in the CSICU. As part of the practice change implementation, a clinical decision algorithm for CXRs was developed following CSICU best practices. Training and education for the practice change was developed and delivered to the CSICU staff which included physicians, advanced practice providers (APPs), and nurses on the unit. Training focused on clinical indications for CXRs and the clinical decision algorithm tool (See appendix A) to be used in CSICU rounds. Based on this tool, the patient either met criteria for a routine daily CXR or for on demand CXR only. If the patient met criteria for a routine CXR then this could be ordered at this time, but if they met criteria for on demand only, then all future CXR were placed based on clinical change or indication only. This clinical decision was documented in the patient's electronic health record (EHR) in the daily ICU note (See appendix B). Door signs (See appendix C) were also placed on those patients who met criteria for on demand CXR so that the radiology ancillary staff could confirm the order placed if there was a conflicting door sign. The implementation team consisted of seven attendings, 14 APPs, and eight rotating fellows.

The structure measures assessed were staff education on implementation with a goal of 100% CSICU staff education. This data was collected by attendance at a staff meeting or with individual confirmation after a group email was sent out with the education slides. This data could be quickly analyzed to track progress and make changes if not enough of the staff could be reached. Training was reinforced and supported by CSICU change champions and was particularly needed with new monthly rotating fellows. The change in EHR was implemented in the daily CSICU note where the decision of CXR was documented 'yes' or 'no' and if the answer is 'yes' then a clinical indication must be documented. Direct feedback was provided to team members or providers if a pattern without documentation of clinical indication or if it was evident that additional education on appropriate clinical condition was needed.

The process measures assessed were the number of patients who qualified for an on demand CXR and the number of on demand CXR ordered. Data was collected on the patients who met the criteria for an on demand CXR by auditing the daily ICU note weekly. This provided feedback in a timely manner and enabled the student project leader to find trends or providers that may need additional education or feedback on clinical decision for CXRs. The number of on demand CXRs ordered was collected through a monthly audit from the Radiology Information System (RIS) report sent through a spreadsheet. This provides a slower feedback opportunity since it is analyzed monthly. This data was used for the run chart and distributed to the unit so that the staff could see the trends over the weeks. Note compliance documentation increased rapidly after EHR implementation and note change. Staff who lagged in compliance were those who used their own decision template or patients who were on the unit prior to the note change and did not have a new template note started. This was rectified with the introduction of the dot phrase that included the needed text to document the clinical decision making. The next problem was that certain providers could delete this section from the note and that was rectified by placing this phrase in a portion of the note that could not be deleted.

Outcome measures (figure 6) assessed was the total number of CXR sent on the unit by the monthly audit from the RIS report. A downside of this report was that it was provided monthly which had a slower feedback opportunity with a monthly analyzation. The spreadsheet document was analyzed for CXR indication and purpose of CXR ordered. These results were more difficult to trend with fewer data points. Patient confidentiality was ensured with data collection where project and patient data was recorded and stored in a locked drawer in the Advanced Practice Office and shredded after 6 months. Patient's identity was de-identified. Data was recorded and retrieved weekly by the QI Project Lead (QI-PL) using the chest radiograph audit forms. The RIS data was requested monthly directly delivered to a password protected laptop. Prior to implementation, the QI project was submitted to the Human Research Protections Office at the University of Maryland and received a non-human research determination.

Results

The structure measure practice change was that 100% of the provider staff were educated on the decision tree algorithm to identify the appropriate patient population eligible for on demand chest radiographs only. The other structural practice change was that there was documentation in the electronic health record (EHR) in the daily critical care note to record the decision and justification for decisions made on the morning CXR. The practice changes made for process measures was to measure compliance of the decision algorithm by documentation in the daily critical care note. There was a consistent increase in compliance of documentation in the daily critical care note. In the three weeks of pre-implementation there was 0% compliance and in week 15 there was 85% of compliance (See figure 4). The practice change made for the other process measure was to decrease routine morning chest radiographs and have them be ordered on demand if there was a clinical concern. There was a trend of decreased chest radiographs starting at week seven with a 20% complying with the algorithm and improving to 67% by week 15. The overall average for the implementation was 56.5% (See figure 5). There was not a consistent trend of total AM CXRs ordered on the unit per patient days (See figure 6). There also was not a consistent trend for total on demand CXRs ordered on the unit per patient days (See figure 7).

When the documentation went live in EHR, the compliance rate greatly increased since it was a mandatory part of the note, but the EHR platform allows for customization so 100% of compliance was not able to be reached since those who used a personalized note did not have the required documentation. Attempts were made for easy integration of the required documentation by creating a smart phrase that could be used in a personalized note. Despite reminders and re-education, some providers were resistant to change and did not include the new smart phrase in their note. There was slow progression of change to decrease ordering routine daily morning chest radiographs and there were associations with the acuity of the patients on the unit. The average number of cardiac surgery patients decreased during the pandemic and there was an increase in patients requiring extracorporeal support and other invasive devices. It was not the mindset to have a progressing post operative cardiac surgery patient on the unit, so it was difficult for the providers to grasp the concept of not needing a routine CXR.

The pandemic and patient population was an unexpected barrier to this project and had major impact of the patient population on the unit. There were mandatory decreased surgical caseloads and utilization of the unit for medical patients admitted with coronavirus complications.

Discussion

Key findings for outcome measures were the reduction of health care related costs with routine daily CXR costing $42,272.16 in September and $33,771.78 in December. The percentage of routine daily CXR were steady in the pre-implementation months August and September and no change one month after implementation in October. There was a sizable decrease of routine daily CXR in the months of November and December. The other outcome measure was the amount of CXR radiation exposure for the patients and in September the ratio compared to total patient days was 0.62 and in December the ratio was 0.47. These cost savings related to reduced CXR protocols are similar to those reported by Tolsma et al. (2015) and Kevenson et al. (2017). Significant decreases in patient radiation exposure from reduced CXRs utilization were reported by Kevenson et al. (2017) and Wu et al. (2020).

Challenges encountered in implementation of the QI project were primarily due to staffing and the pandemic. The CSICU climate made implementation difficult because of a large leadership change including a new medical and surgical director. The pandemic also led to a large turnover of nursing staff and an increase in contract nurses. The rotation of the CSICU fellows was 2-4 weeks requiring frequent education about the practice change. The culture change was slow due to the large turnover and rotation of staff. There was a high acuity of patients during COVID and decreased number of cardiac surgery patients.

Conclusion

The usefulness of this QI project is to improve cost effective and efficient patient care without sacrificing patient safety and thoroughness. The EHR usage for implementation ensures compliance and sustainability since it is part of mandatory documentation. EHR also helps with data collection since reports can be easily created in the EHR. Frequent distribution of the trends and results can help motivate staff to continue the practice change if the outcomes are positive. The end of year budgeting and cost savings will motivate leadership to continue with the practice change.

While culture change is often slow in the CSICU, gradual change led to increased compliance to the practice change of reduced CXRs. A benefit of new and a large turnover of staff is that old unit cultures can be changed, and new unit culture can be developed. Project champions will continue to help to sustain the practice change by reinforcing training and to help answer any questions. The next steps of this project would be to broaden the patient population that these concepts apply to so that other patient populations can benefit from this practice change. In the EHR, there are best practice alerts that notify the ordering provider for drug related information and there should be this practice change when trying to order a routine morning CXR. Additionally, another next step should be to remove the morning CXR from the standard postop order set.

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Kevenson, B., Clouser, R., Hamlin, M., Stevens, P., Stinnett-Donnelly, J., & Allen, G. (2017). Adding value to daily chest x-rays in the ICU through education, restricted daily orders and indication-based prompting. *BMJ Open quality, 6*(e0000072), 1-6. https://doi.org/10.1136/bmjoq-2017-0000724

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Tolsma, M., Rijpstra, T., Rosseel, P., Scohy, T., Bentala, M., Mulder, P., & Meer, N. (2015). Defining indications for selective chest radiography in the first 24 hours after cardiac surgery. *The Journal of Thoracic and Cardiovascular Surgery, 150*(1), 225-229. https://doi.org/10.1016/j.jtcvs.2015.04.026

Wu, Y., Rose, M., Freeman, M., Richard-Lany, N., Spaulding, A., Booth, S., Kelly, D., & Franco, P. (2020). Reducing chest radiography utilization in the medical intensive care unit. *Journal of American Association of Nurse Practitioners, 32,* 390-399. https://doi.org/ 10.1097/JXX.0000000000000256

Tables

Table 1

Evidence Review Table

Citation: Ganapathy, A., Adhikari, N., Spiegelman, J., & Scales, D. (2012). Routine chest x-rays in intensive care units: A systematic review and meta-analysis. Critical Care Journal, 16(2). https://doi.org/ 10.1186/cc11321					Level (Melnyk): I
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Systematically review the available literature evaluating the effect on clinical outcomes of abandoning routine chest radiographs (CXRs) in favor of a more restrictive approach."	Meta Analysis	Sampling Technique: Studies from National Library of Medicine's Medline database from January 1, 1950 to December 3, 2008. Power analysis: None completed Group Homogeneity: Average age 62.8 Inclusion: Exclusion: Trials enrolling pediatric patients (<18 years of age) Out of 23 studies initially found, 8 were used for the analysis	Intervention: Task force of multiple critical care societies met to develop evidence informed summaries. They were to evaluate each proposed idea on strength of evidence, prevalence, aggregate cost, relevance, and innovation.	DV: ICU mortality, length of mechanical ventilation/hospital stay, or adverse event rate Measurement tool (reliability): Cost savings were calculated with an equation using ventilator days. University HealthSystem Consortium database was used for mortality rates. The internal event reporting system was used to analyze reports of endotracheal misplacements or missed diagnoses. Measurements were done by the intensivists	Statistical Procedures(s) and Results: A z test was performed to examine the overall effect. Univariate and multivariate regression meta-analyses were performed to identify a subgroup in which daily routine chest radiography was possibly beneficial. Pooled analysis revealed that the elimination of daily routine chest radiography did not affect either hospital or ICU mortality (*P* = 0.78) and (*P* = 0.4). There was no significant difference in ICU length of stay (LOS) (*P* = .25), hospital LOS (*P* = .18), and ventilator days (*P* = .15) between the on-demand and daily routine groups. Regression analyses failed to identify any subgroup in which performing daily routine chest radiography was beneficial.

Citation: Halpern, S., Becker, D., Curtis, R., Fowler, R., Hyzy, R., Kaplan, L., Rawat, N., Sessler, C., Wunsch, H., & Kahn, J. (2014). An official American thoracic society/American association of critical care nurses/American college of chest physicians/society of critical care medicine policy statement: The choosing wisely top 5 list in critical care medicine. American Journal of Respiratory and Critical Care Medicine, 190(7), 818-826. https://doi.org/ 10.1164/rccm.201407-1317ST					Level (Melnyk): VII
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"To present the Critical Care Societies Collaborative's Top 5 list in Critical Care Medicine and describe its development."	N/A. Task force	Sampling Technique: N/A Power analysis: N/A Group Homogeneity: N/A Inclusion: N/A Exclusion: N/A	Intervention: Task force of multiple critical care societies met to develop evidence informed summaries. They were to evaluate each proposed idea on strength of evidence, prevalence, aggregate cost, relevance, and innovation.	Five recommendations vetted and endorsed for the Choosing Wisely Campaign.	Recommendation 1: Do not order diagnostic tests at regular intervals (such as every day), but rather in response to specific clinical questions. Recommendation 2: Do not transfuse RBCs in hemodynamically stable, nonbleeding ICU patients with an Hb concentration greater than 7gdL Recommendation 3: Do not use parenteral nutrition in adequately nourished critically ill patients within first 7 days of ICU stay Recommendation 4: Do not deeply sedate mechanically ventilated patients without specific indication and without daily attempts to lighten sedation Recommendation 5: Do not continue life support for patients at high risk for death or severely impaired functional recovery without offering patients and their families an alternative of care focused entirely on comfort

Citation: Kevenson, B., Clouse, R., Hamlin, M., Stevens, P., Stinnett-Donnelly, J., & Allen, G. (2017). Adding value to daily chest x-rays in the ICU through education, restricted daily orders and indication-based prompting. *BMJ Open Quality*, *6*(e00072). https://doi.org/10.1136/bmjoq-2017-000072					Level (Melnyk): III
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Based on anecdotal knowledge of local practice, we hypothesized that our adult Intensive Care Unit (ICU) practice overused daily CXRs, and that a systematic initiative of targeted education and a modified electronic ordering system could lead to a significant reduction in potentially unnecessary CXRs."	Prospective, Nonrandomized study	Sampling Technique: Convenience Eligible Participants: Patients admitted to a medical or surgical ICU # Eligible: 7,078 ICU patients Power analysis: None completed Group Homogeneity: Patient characteristics were not discussed in the article Inclusion: Patients admitted to 21 bed MICU and 21 bed SICU Exclusion: Admission Day, any day requiring a procedure that warranted a follow up CXR	Control: N/A Intervention: Education occurred from 6/2013 to 3/2014 for all critical care staff and ancillary staff. System based changes included removing the daily option for portable chest radiograph order from EHR and added a prompt to the ICU rounding checklist if a CXR was clinically indicated that day	DV: Patient census days with invasive mechanical ventilation excluding the admission date or days with invasive procedures. Measurement tool (reliability), time, procedure: Studies were evaluated using CONSORT criteria for randomized controlled studies and STROBE criteria for observational studies. Studies should satisfy at least 5 of the 22 CONSORT or STROBE criteria.	Statistical Procedures(s) and Results: Origin software was used for paired t-tests to compare monthly rates of daily CXRs (per 1000 ventilator days) over the 12 months before and after the intervention. Monthly CXRs performed in the MICU decreased 64% per 1000 included ventilator days ($p<0.001$). Monthly CXRs in the SICU decreased 35% per 1000 included ventilator days ($p<0.001$). Estimated cost savings was $322,000 to $363,000 over the 2-year period

Citation: Salhei, M., Saberi, K., Rahmanian, R., Bakhshandeh, A., & Sharifi, S. (2017). Assessment of limited chest x-ray technique in post cardiac surgery management. *Annals of Cardiac Anesthesia, 20*(1), 38-41. https://doi.org/ 10.4103/0971-9784.197829					Level (Melnyk): II
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"The objective of this study is to investigate the safety of elimination of chest radiography in the postcardiac surgery Intensive Care Unit (ICU)."	Randomized, double blinded study	Sampling Technique: Convenience Participants: Patients admitted to the Cardiac ICU between September 2014 and January 2016 # Eligible: 1150 # Accepted: 978 # Control: 489 # Intervention: 489 Power analysis: None completed Group Homogeneity: Patient Characteristics with average age of patients were 60 with 58% of participants being male Inclusion: Patients admitted the Cardiac ICU Exclusion: Patients requiring intra-aortic balloon pump (IABP), redo operations, concern for retained foreign body during surgery, patients under 2 years old, and ICU greater than 48 hours, and death within first 48 hours	Control: Routine chest radiograph (CXR) group where one CXR was obtained at time of admission, after chest tube drains removed, and last one when patient transferred out of ICU Intervention: Limited CXR group examined with heart and lung auscultation, echocardiography if needed, invasive hemodynamic monitoring, urine output, and body temperature. A CXR was obtained only if the patient required an intervention. One CXR was obtained when the patient was transferred out of ICU	DV: Abnormalities found on CXR requiring intervention Measurement tool (reliability), time, procedure: CXR was utilized for confirmation of any signs that had been detected clinically. CXR analyzed by intensivist. Abnormalities found in the CXR were documented and if the CXR resulted in a change in therapy	Statistical Procedures(s) and Results: 523 abnormalities in RCXR group and 154 occasions in LCXR group resulted in 26.73% diagnostic efficacy for RCXRs and 28.57% for LCXR. From 1956 CXR that was taken in RCXR group, 72 occasions required intervention (3.68%) and 84 cases out of 539 (15.58%) LCXR needed an action to therapy. This means a 14.40% (72 out of 500) in RCXRs' abnormalities and 56.00% (84 out of 150) of LCXRs' abnormalities were accompanied with some interventions

Citation: Tolsma, M., Rijpstra, T., Rosseel, P., Scohy, T., Bentala, M., Mulder, P., & Meer, N. (2015). Defining indications for selective chest radiography in the first 24 hours after cardiac surgery. *The Journal of Thoracic and Cardiovascular Surgery*, *50*(1), 225-229. https://doi.org/ 10.1016/j.jtcvs.2015.04.026					Level (Melnyk): III
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Aim was to study the diagnostic and therapeutic efficacy of this new CXR strategy, performing CXRs after cardiac surgery for specified indications only."	Prospective, Observational Cohort Study	Sampling Technique: Convenience Participants: Patients admitted to the Cardiac ICU in 2012 # Eligible: 1102 Power analysis: None completed Group Homogeneity: Patient Characteristics with average age of patients were 69 +/-9 with 73% of participants being male Inclusion: Patients admitted the Cardiac ICU Exclusion: None	Control: N/A Intervention: Direct postoperative CXR upon ICU arrival was performed routinely for certain specified indications. A CXR could be obtained throughout the first postoperative period according to other indications determined by an ICU physician after an assessment	DV: Abnormalities found on CXR Measurement tool (reliability), time, procedure: All CXRs were assessed by both a radiologist and an ICU physician. The CXR findings were divided into minor and major findings. Only new findings were analyzed, and abnormalities that were already present on a preoperative CXR were not taken into consideration	Statistical Procedures(s) and Results: Differences were tested using Fisher's exact test or X^2 analysis. The diagnostic efficacy of CXRs for major abnormalities was higher for the postoperative on-demand CXRs (n=27%) than for the routine CXRs taken the morning after surgery (n=73%) (6.6% vs 2.7%, P=0.004). The therapeutic efficacy was higher for the on-demand CXRs, whereas the need for intervention after the next-morning, routine CXRs was limited to 5 patients (4.0%vs 0.6%, P<.001). None of these patients experienced a major adverse event.

Citation: Trumbo, S., Iams, W., Limper, H., Goggins, K., Gibson, J., Oliver, L., Leverenz, D., Samuels, L., Brady, D., & Kripalani, S. (2019). Deimplementation of routine chest x-rays in adult intensive care units. *Journal of Hospital Medicine, 14*(2), 83-89. https://doi.org/10.12788/jhm.3129					Level (Melnyk): III
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"On demand strategies may safely reduce CXR ordering by 32-45%."	Prospective, Nonrandomized Study	Sampling Technique: Convenience Eligible Participants: Those admitted to Cardiovascular Intensive Care Unit (CVICU) and Medical Intensive Care Unit (MICU) between October 2015 and June 2016 # Accepted: CVICU: 2,027 MICU: 3,902 # Control: CVICU: 1,180 MICU: 2,378 # Intervention: CVICU: 847 MICU: 1524 Power analysis: None completed Group Homogeneity: Patient characteristics chart described in Table 1 between CVICU and MICU control and interventional groups Inclusion: All patients Exclusion Criteria: None	Control: No teaching and ordering CXR at regular intervals without indication Intervention: Didactic session on proper CXR ordering practices, peer champions, data audits, and feedback to providers through weekly emails. Two Plan-Do-Study-Act cycles. Disseminating promotional flyers, holding meetings with stakeholders, providing monthly CXR ordering rates.	DV: CXR ordering data Measurement tool (reliability), time, procedure: For quantitative data daily CXRs ordered per patient per day by hospital unit evaluated. For quantitative evaluation embedded observation and semi structured interviews with stakeholders. Used Consolidated Framework for Implementation Research (CFIR) to determine major facilitators and barriers. The outcome measurements were completed by the providers in the MICU and CVICU units. The CXR ordering rates and factors facilitating or inhibiting deimplmentation were analyzed.	Statistical Procedures(s) and Results: CVICU: Median baseline was 1.16 CXR per day and rate dropped to 1.07 ($p<0.001$) MICU: Baseline was 0.60 per patient per day and rate drop was not statistically significant. 20% absolute reduction in the CVICU. Linear regression used to analyze data from baseline to intervention

Citation: Wu, Y., Rose, M., Freeman, M., Richard-Lany, N., Spaulding, A., Booth, S., Kelly, D., & Franco, P. (2020). Reducing chest radiography utilization in the medical intensive care unit. *American Association of Nurse Practitioners, 32*(5), 390-399. https://doi.org/10.1097/JXX.0000000000000256					Level (Melnyk): III
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Reducing harm from unnecessary radiation and change practice habits of the multi-disciplinary team"	Prospective Study	Sampling Technique: Convenience Eligible Participants: Adults greater than 18 years old who required endotracheal intubation and mechanical ventilation admitted between 10/2014 and 2/2018 Power analysis: None completed Group Homogeneity: Patient characteristics were not discussed in the article Exclusion Criteria: Patients with tracheostomy, those with neurological abnormalities, and those who had undergone cardiothoracic surgery	Control: Preintervention period of 1 year Intervention: 3 phases Phase 1: Staff survey consisting of eight questions assessing the reasons and frequency of ordering CXRs in MICU to understand providers' perspectives on CXR ordering practice. Posters placed within department of does my patient need a CXR tomorrow? Routine CXR was removed from EHR order set Phase 2: Duplicate CXR alert introduced in EHR if an order was placed within 6 hours of a previous order Phase 3: Survey of 4 questions assessing reasons and frequency of ordering CXRs and frequency of reading CXR reports. 2 education sessions held to utilize beside US	DV: Number of CXRs per patient day, number of routine and on-demand CXRs Data of ICU LOS, mortality rate, and ventilator days collected pre and post intervention Reduction of radiation was calculated based on number of CXR performed and costs were determined using Mayo Clinic Billing and Insurance Price Estimator.	Statistical Procedures(s) and Results: Phase 1: 27 respondents to survey (N=30, response rate 90%) Phase 2: 0.190 decrease in number of CXRs per census post intervention ($p=0.02$) Phase 3: 0.090 point decrease of CXRs per census post intervention ($p=0.04$) Ventilator days decreased by 0.289 ($p=0.02$) in phase 1, increased by 0.129 ($P<0.01$) in phase 2 and no change in phase 3. Decrease of $31,620 during in phase 1 to 3 Little change in ICU mortality in phase 3 ($p<0.01$)

Rating System for Hierarchy of Evidence

Level of Evidence	Type of Evidence
I (1)	Evidence from systematic review, meta-analysis of randomized controlled trails (RCTs), or practice-guidelines based on systematic review of RCTs.
II (2)	Evidence obtained from well-designed RCT and/or reports of expert committees.
III (3)	Evidence obtained from well-designed controlled trials without randomization.
IV (4)	Evidence from well-designed case-control and cohort studies
V (5)	Evidence from systematic reviews of descriptive and qualitative study
VI (6)	Evidence from a single descriptive or qualitative study
VII (7)	Evidence from the opinion of authorities

Melnyk, B.M. & Fineout-Overholt, E. (2015). "Box 1.3: Rating system for the hierarchy of evidence for intervention/treatment questions" in *Evidence-based practice in nursing & healthcare: A guide to best practice (3rd ed.)* (pp. 11). Philadelphia, PA: Wolters Kluwer Health.

Table 2

Synthesis Review

Evidence Based Practice Question (PICO): In the adult cardiac surgery intensive care unit (ICU) patient, will implementing a patient selection algorithm with on demand CXR bundles reduce daily routine chest radiographs (CXRs), reduce ICU patient radiation exposure, and CXRs costs?			
Level of Evidence	**# of Studies**	**Summary of Findings**	**Overall Quality**
I	**1**	Ganapathy, A., Adhikari, N., Spiegelman, J., and Scales, D. (2012) presented a meta-analysis on the necessity of routine CXR in the intensive care unit. The primary data showed that the ICU mortality did not demonstrate a statistical significance between clinically indicated and daily routine CXR groups.	B. Searched for randomized and quasi randomized controlled trials (RCTs) and before after observational studies comparing a strategy of routine CXRs to a more restrictive approach. Nine studies were included in the meta-analysis
III	**4**	Trumbo, S., Iams, W., Limper, H., Goggins, K., Gibson, J., Oliver, L., Leverenz, D., Samuels, L., Bady, D., and Kripalani, S. (2018) found savings of up to $18,000 per year with a CXR ordering rate of 1.16 per patient day and after then intervention period, it decreased to 1.07 (P<0.001). Salehi, M., Saberi, K., Rahmanian, M., Bakhshandeh, A., and Sharifi, S. (2017) found that abolishing routine CXRs in the ICU would not be harmful for patients and can be based on clinical status and other safer imaging techniques like bedside US. The limited CXR group relied on non-radiographic information for assessments and the routine CXR group received a CXR daily regardless of clinical indication. Patients excluded were those with intra-aortic balloon pumps and redo cardiac operations. Kevenson, B., Clouser, R., Hamlink M., Stevens, P., Stinnett-Donnelly, J., and Allen, G. (2017) found an annual savings of $191,600 to $224,2000 post restriction of routine daily CXR ordering. Wu, Y., Rose, M., Freeman, M., Richard-Lany, N., Spauling, A., Booth, S., Kelly, D., and Franco, P. (2020) found decrease	B. Used two well defined units from a specific time period using control data from a historical period. Well organized study with clear interventions implemented. Definitive conclusions. Large sample but no power analysis or control B. Clear defined study period with two non-randomized groups with clear defining methods of each group. Definitive conclusions. Single center and single unit study with a sample size of 978. This approach would be generalizable to other cardiac surgery ICUs B. Clear defined pre and post implementation periods with reproducible study setup. Definitive data collected with equation calculation of CXRs saved. Definitive conclusions. 2 units used with multi-disciplinary team approach. No power analysis so a type 1 or type 2 error is possible B. Clear defined study period with reproducible results. Definitive conclusion but has no power analysis so a type 1 or type 2 error is possible

		of calculated radiation exposure census decreased with statistical significance from 0.011 to 0.008 mSV. The patients CXR costs also decreased by $7,750 per month and the ICU mortality rate per census remained stable.	
VII	**1**	Halpern, S., Becker, D., Curtis, R., Fowler, R., Hyzy, R., Kaplan, L., Rawat, N., Sessler, C., Wunsch, H., & Kahn,J. (2014) represent the American Thoracic Society, the American Association of Critical Care Nurses, the American College of Chest Physicians, and the Society of Critical Care Medicine on a collective policy statement of recommendations. Recommendation #1 is to no order diagnostic tests at regular intervals but rather in response to specific clinical questions. They support the evidence that routine chest radiography are rarely indicated and may be harmful. They confirm that les than half of the images actually prompt change in management.	B. Policy statement from many credible societies that represent the collective thoughts of Choosing Wisely Campaign. Clear definitive conclusions and providing logical argument for opinions.

The studies use a combination of surgical and medical units. Some studies specifically want to analyze intubated patients only in the ICU while others measure CXR based on ICU status regardless of invasive ventilation. The studies range from randomized to non-randomized studies.

Figure 1: Donabedian's Quality Framework

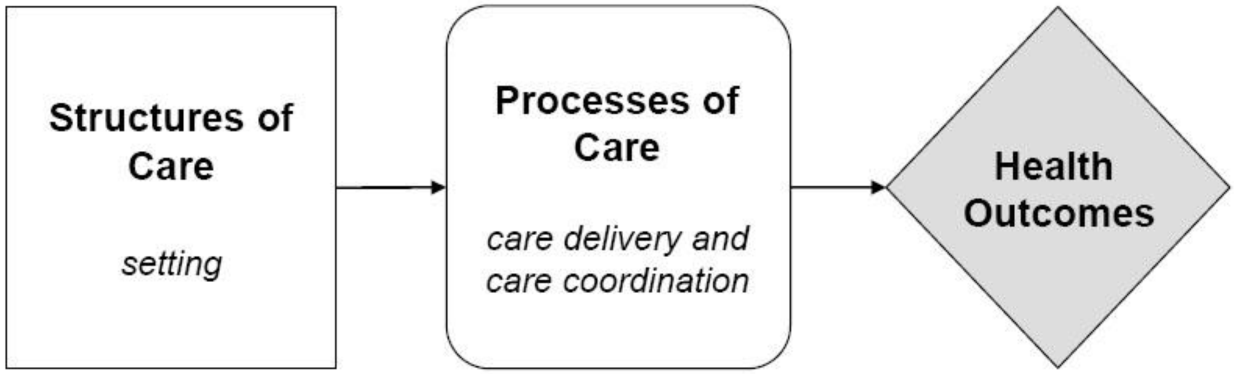


Figure 2: Conceptual Framework of Complex Innovation Implementation

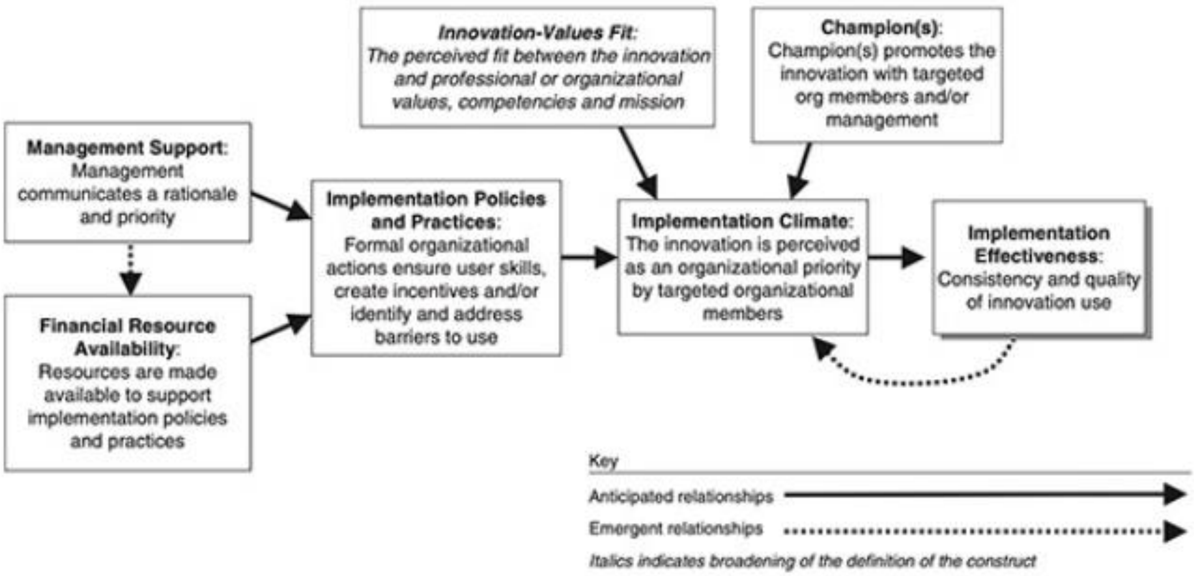


Figure 3: Current Process Flow Map

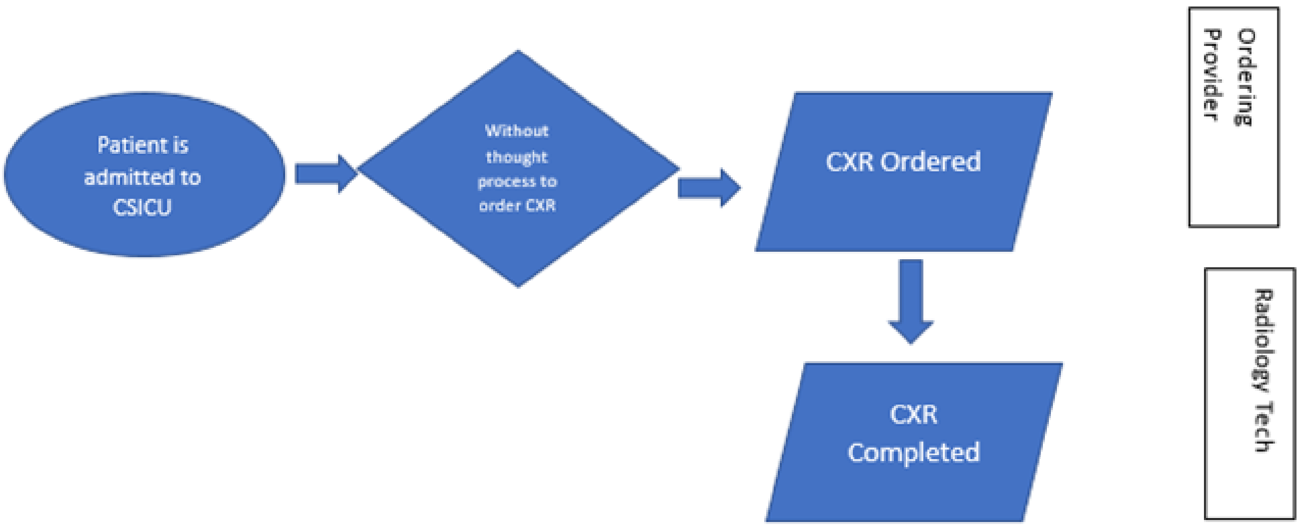


Figure 4: Run Chart of Process Measure: Screening of patients eligible for on demand CXR based on algorithm

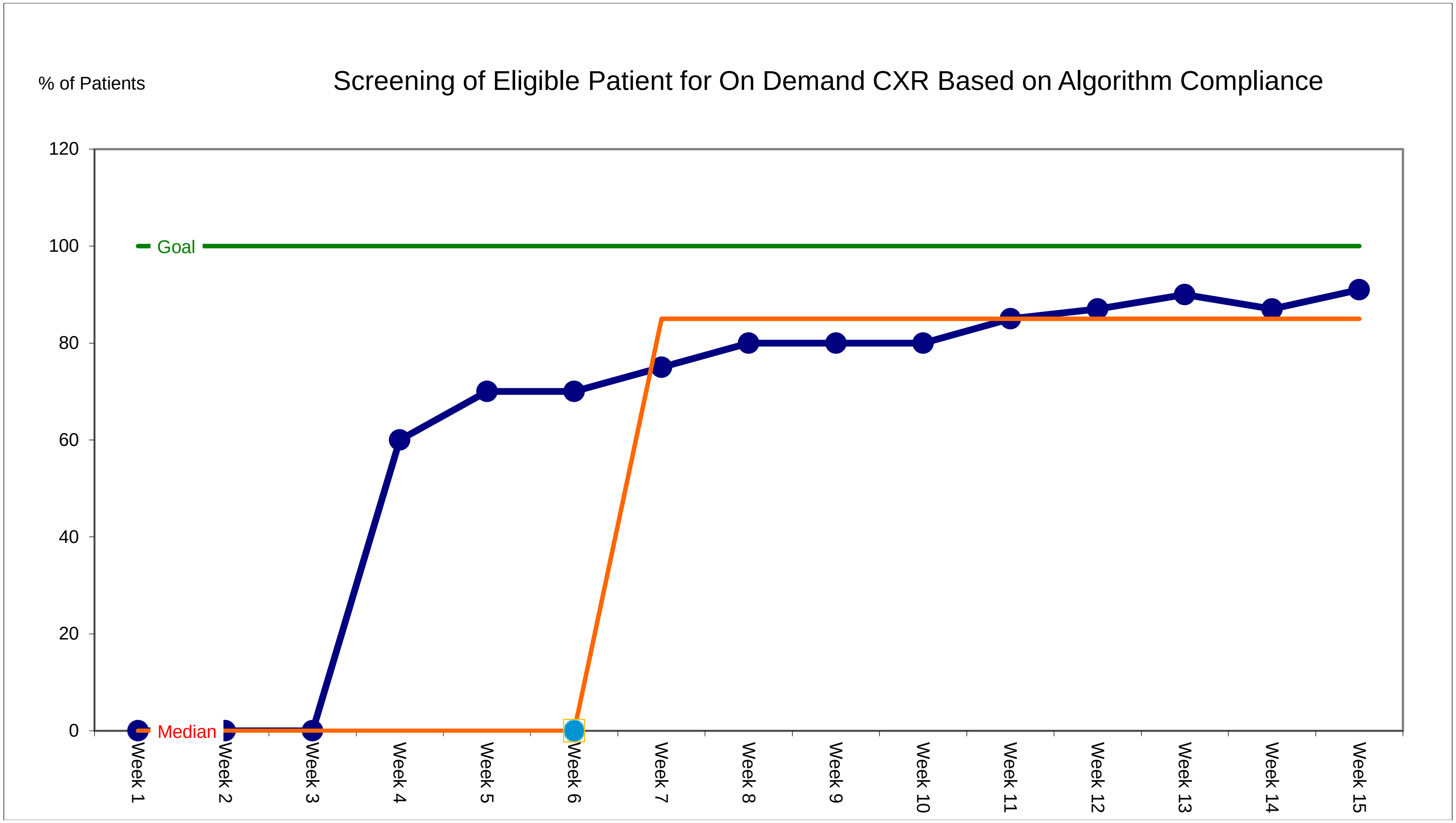


Figure 5. Run Chart of Process Measure: The number of patients who were not ordered an AM CXR out of those eligible

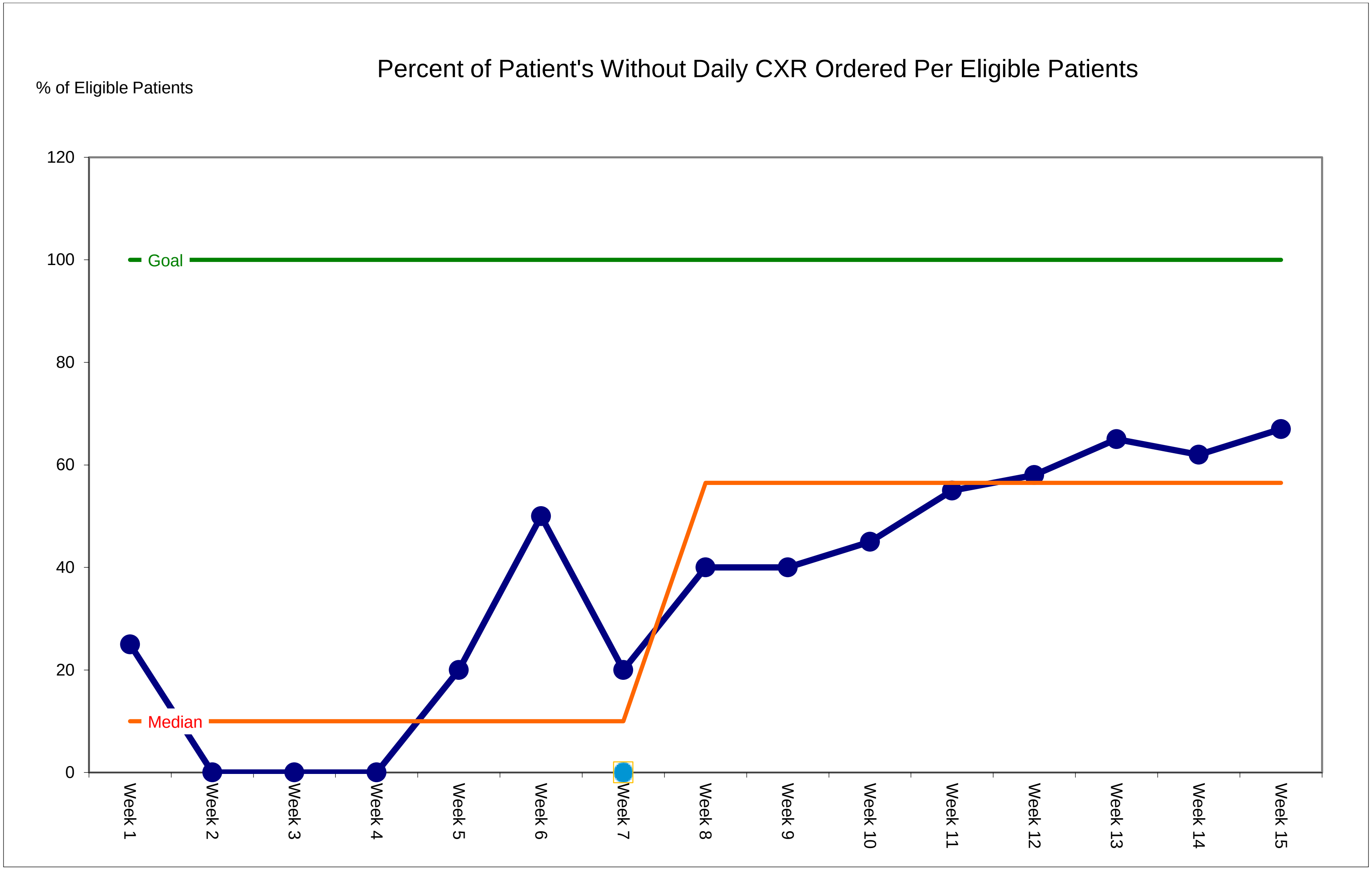


Figure 6. Chart of Outcome Measure: Total number of AM CXRs ordered out of total patient census days on unit

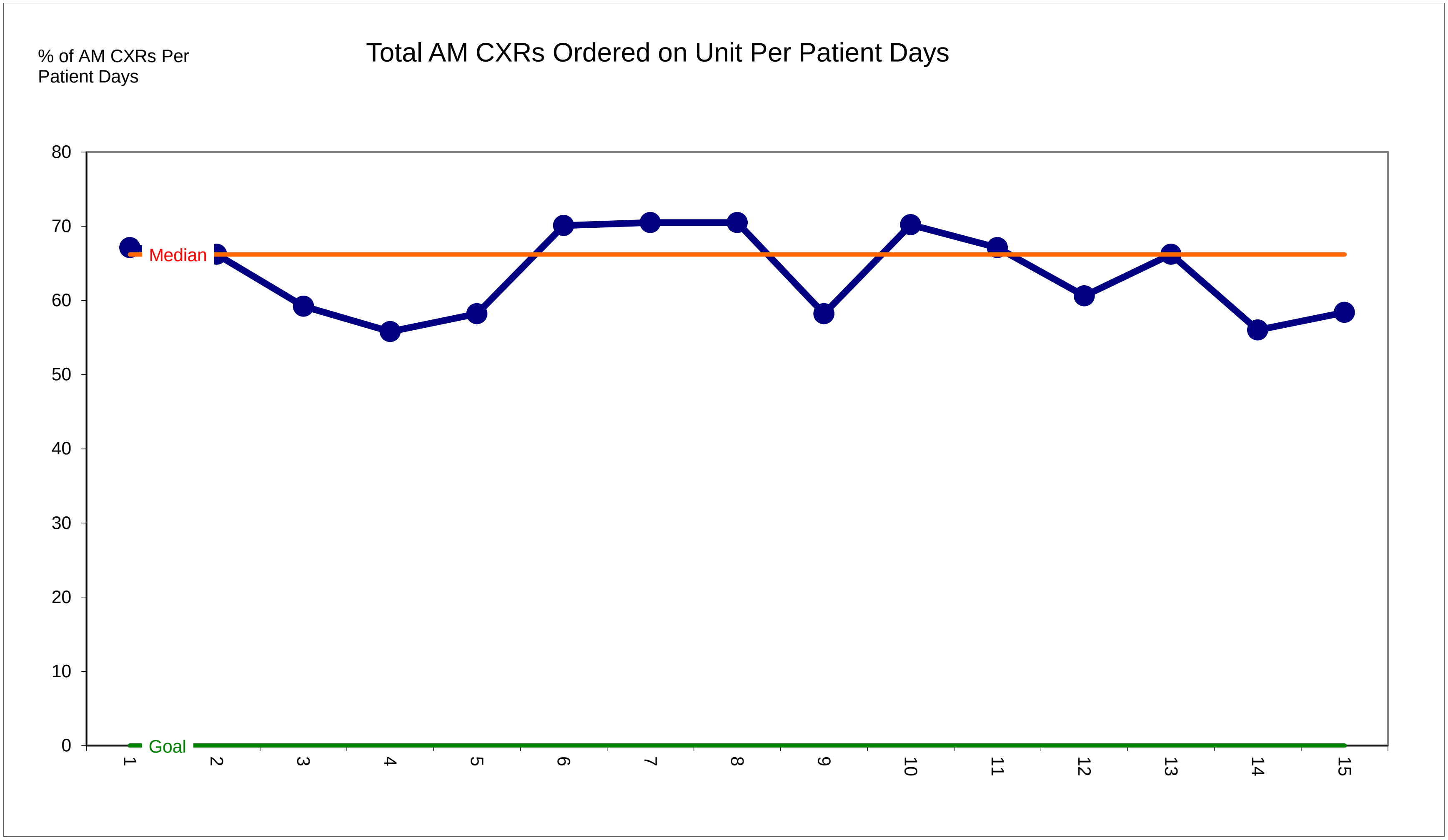
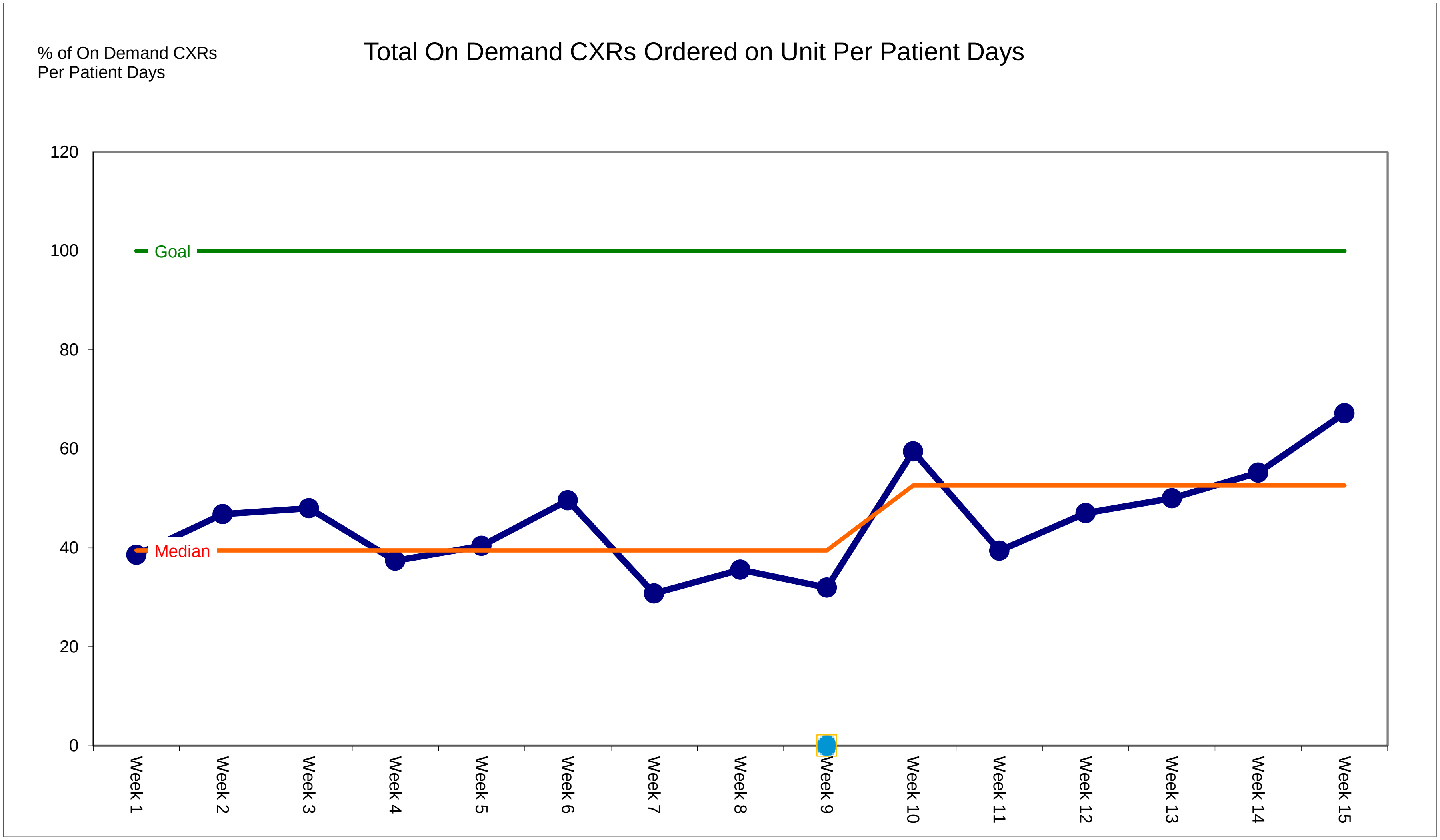
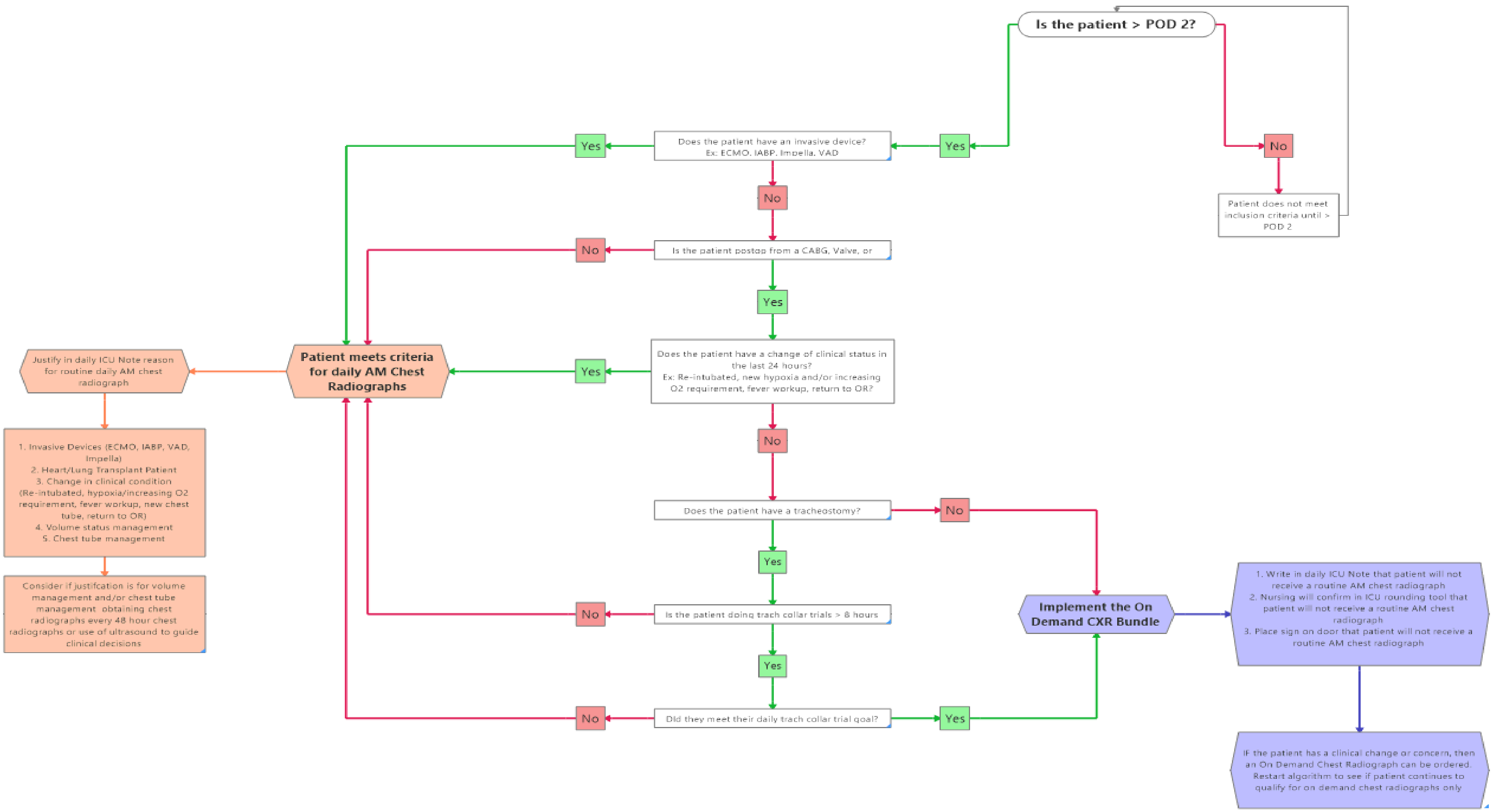


Figure 7. Run Chart of Outcome Measure: Total number of on demand CXRs ordered out of total patient census days on unit



Appendix A

Morning CXR Decision Algorithm



Appendix B

Daily Intensive Care Rounding Tool: Respiratory Section

Respiratory Plan: ____ Daily CXR Ordered? ___Y____N Reason for CXR Ordered__________________________ FiO2 goal_______________

Appendix C

Door Sign

Appendix D

Chest Radiograph Audit Forms

Date: ______________ Patient MRN: _________________________

Surgical Procedure: ___________________ Surgical Date: ___________________________

1. Routine Daily Chest Xray Ordered? ☐ Yes ☐ NO

2. Reason for ordering routine daily chest Xray (From ICU Note)_________________________

3. Patient intubated? ☐ Yes ☐ No

4. A. Patient have a tracheostomy? ☐ Yes ☐ No
   B. If yes, are they doing trach collar trials? ☐ Yes ☐ No
   C. If yes, what was their goal ________________ D. Did they meet their goal? ☐ Yes ☐ No

5. A. Do they have surgical chest tubes in place? ☐ Yes ☐ No

   B. Total drainage in last 24 hours __________________________

Note: Reasons for routine daily AM chest Xray
A. Invasive devices (ECMO, IABP, VAD, Impella, etc.)
B. Heart/Lung transplant
C. Change in clinical condition (Re-intubated, hypoxia, fever workup, new chest tube, return to OR, etc.)
D. Volume status management
E. Chest tube management
F. Failed Tracheostomy Trach Collar Trial