A LEAN Approach to Intravenous Antibiotic Distribution in a Tertiary Care Academic Hospital

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KINGSTON GENERAL HOSPITAL
DEPARTMENT OF PHARMACY SERVICES

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A LEAN Approach to Intravenous Antibiotic Distribution in a Tertiary Care Academic Hospital

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ABSTRACT

Background: LEAN is a quality improvement methodology that identifies and eliminates waste in processes. LEAN principles, such as value stream mapping, may be applied to the hospital IV antimicrobial distribution process to increase resource use efficiency while ensuring patient safety.

Objectives: Primarily to define the current IV antibiotic distribution process at Kingston General Hospital (KGH) and to identify opportunities for improvement in resource use efficiency. Secondarily to reduce waste, categorized as non-value-added time from a patient perspective or by cost of unusable product, in the IV antibiotic distribution process.

Methods: A stakeholder group of pharmacy personnel and a patient experience advisor was formed. Current state value stream maps (VSMs) were constructed with direct observation for time estimates for each of the three, not previously defined, distribution streams: (1) central intravenous admixture service (CIVAS) preparation, (2) CIVAS-prepared minibags stocked in automated dispensing cabinet (ADC), and (3) vial stock in ADC used with point-of-care activation device. Each process step was categorized into ‘value-added’, ‘non-value-added’ (pure waste), and ‘non-value-added, but essential’. Opportunities for process improvement were identified, and education of staff regarding IV antibiotic order entry into the pharmacy information system was chosen for implementation using a Plan-Do-Study-Act (PDSA) cycle. Representative product waste and adherence to standardized order entry procedures were assessed before and after education.

Results: Current state VSMs of ampicillin, cefazolin and piperacillin-tazobactam distribution were constructed, representing distributions streams 1, 2 and 3, respectively. Value added time was found to be the highest with stream 3, piperacillin-tazobactam at 26% (16 min), followed by stream 1 at 21% (14 min), then stream 2 at 14% (12 min). Stream 2 had the highest proportion of non-value-added (pure waste) with 74% (62 min), followed by Stream 1 at 67% (45 min), then...
Stream 3 at 64% (40 min). No statistically significant difference was observed in resource waste or policy adherence before and after staff education on IV order entry processes (waste, $1804 versus $1840; adherence, 49% versus 46%, NS).

**Conclusions:** Using LEAN methodology, the IV distribution stream associated with the most efficient resource use is ADC vial stock intended for use with point-of-care activation device, but resource waste is still substantial. A PDSA intervention focused on PIS order entry in all 3 streams failed to demonstrate waste reduction. Exploration of further opportunities identified should be undertaken.

**Key Words:** Quality Improvement, Intravenous Antibiotics, LEAN Methodology, Hospital Pharmacy, PDSA Cycle

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**Word Count:** abstract = 393, manuscript = 3,868
INTRODUCTION

To improve the quality of health care, initiatives are moving away from increasing the number of services provided to focusing on refining processes that are currently in place.\(^1\) Operational efficiencies, such as standardization, that optimize value for money and maintain or improve patient safety are being pursued at Kingston General Hospital (KGH).\(^2,3\)

LEAN methodology is an approach to quality improvement that examines the continuous flow of product, human resources, and information within a process.\(^4\) The goal of a LEAN analysis is to eliminate waste, thereby increasing the value-added portion of the process. Examples of LEAN methodology include root cause analysis, value stream maps, 5S (sort, set in order, shine, standardize, sustain), and PDSA (plan, do, study, act) improvement cycles, among others.\(^4\) KGH has adopted a LEAN approach to departmental processes, striving to reduce waste and improve quality, thus enhancing efficiency within patient care delivery practices.

Intravenous (IV) antibiotic distribution is an ideal area to focus on quality improvement, as it is one of the most resource-intensive medication use processes. A significant portion of the workload of Pharmacy Services’ Centralized Intravenous Admixture Service (CIVAS) is comprised of IV antibiotics. Several professional, accreditation and legal standards must be met throughout the multi-step IV antibiotic dose production and distribution stream to ensure a safe dose is available for administration to patients in a timely manner.\(^5\) In addition, regulation of hospital pharmacies by the Ontario College of Pharmacists is now in effect, leading to a renewed focus on the potential benefits of commercially available IV antibiotic admixtures.\(^5\)

Depending upon the specific IV antibiotic, there are different distribution streams of both production and transportation to get the product ready for administration to the patient. Each stream varies in terms of influences on waste and safety. Seven wastes that have been identified in health care include overproduction, inventory, waiting, transportation, defects, staff
movement, and unnecessary processing.\textsuperscript{6} The opposite of wasteful is value-added. In healthcare, a value-added activity may be defined as an activity that the patient wants or needs, that is done correctly, and the activity must change the form/fit/function, as considered from the patient perspective.\textsuperscript{4}

Each distribution stream has positive and negative influences on value-added, non-value-added but necessary, and non-value-added components. These influences include pharmacist review, product selection, beyond use dating, and nursing time. For example, the traditional CIVAS stream provides a pharmacist-reviewed, patient-specific labeled product at low risk for contamination, but requires daily transportation to the patient care unit and may lead to excessive central production due to batching. Automated dispensing cabinets (ADCs), stocked with non-patient-specific IV admixtures for Registered Nurse (RN) retrieval, facilitate timely administration to the patient, but offer opportunity for access prior to pharmacist review, potential inappropriate product selection, and may lead to waste through excessive stock on unit, given product-specific beyond use dating and utilization rate. A third stream involves stocking ADCs with non-patient-specific vials requiring point-of-care (POC) activation by the RN using MiniBag Plus®. This stream minimizes product waste, but introduces potential for selection error and contamination if an incorrect mode of preparation is employed.\textsuperscript{7} It also detracts RN time from direct patient care.

The goal of this project was to define the current IV antibiotic distribution process streams, identify opportunities for improvement and to reduce waste, categorized as non-value-added time from a patient perspective. The focus of this ‘value for money’ approach is to ensure that the right drug gets to the right patient at the right time in a safe and accurate format, while minimizing the cost of unusable product.
OBJECTIVES

Primary

1. To define current processes of IV antimicrobial distribution at Kingston General Hospital using value stream mapping.

Secondary

1. To identify opportunities for improvement in the IV antibiotic distribution process.
2. To select a single improvement opportunity and conduct a plan, do, study, act (PDSA) cycle.
3. To make recommendations to decrease time and product waste in the IV antibiotic distribution process.
METHODS

Project Management Plan

The primary author prepared a project management plan to guide the project. The completed plan is found in Appendix A.

A project stakeholder group was assembled with representatives from pharmacy technician, pharmacist, patient experience advisor, and pharmacy management groups.

Value Stream Mapping

The stakeholder group met to construct comprehensive current state value stream maps of IV antibiotic distribution to adult inpatients using the guiding principle of “80% of the time”. Three distribution streams were mapped out:

(1) CIVAS - traditional patient-specific admixture via central IV admixture service, represented by IV ampicillin;

(2) Minibag via ADC – ready-to-administer, non-patient-specific IV admixture for retrieval at time of need from ADC, represented by IV cefazolin 2 grams; and

(3) Vial via ADC – vial for reconstitution using point-of-care (POC) activation device (Minibag Plus®) for retrieval and preparation by nurse at time of need from ADC, represented by IV piperacillin-tazobactam 3.375 grams and 4.5 grams.

Each of the major process steps from order entry into pharmacy information system (PIS) to production of an IV dose in a safe and appropriate format ready for patient administration was identified. Each process step was categorized, using the patient perspective wherever possible, as (i) value-added (e.g., selection of correct drug stock from ADC), (ii) non-value-added, but essential (e.g., transportation from CIVAS to patient care unit), or (iii) non-value added (pure
waste) (e.g., CIVAS patient-specific label waiting on printer). When possible, direct observation was employed to estimate process step times. The value stream map figures were designed using Microsoft Visio™. Several opportunities for improvement in the IV antimicrobial distribution streams were identified by stakeholders and were recorded during the mapping process.

**Improvement Opportunities Classification**

Improvement opportunities identified were classified by the authors using a PICK chart based on the potential impact and resources required. Opportunities with potential high impact and low resource use requirements were classified as “implement (I)”, those with high impact, high resource use as “challenge (C)”, those with low impact, low resource use as “possible (P)” and those with low impact, high resource use as “kibosh (K)”.

**Improvement Implementation via “Plan, Do, Study, Act” (PDSA) Cycle**

One of the opportunities classified in the “implement” quadrant of the PICK chart was selected to reduce non-value-added resource use through conduction of a PDSA cycle. A PDSA work plan was created using an institutional template. The completed work plan is attached as Appendix B.

**Plan**

To reduce variability, the opportunity selected was to re-educate pharmacy staff on standardized PIS order entry procedures for IV antibiotics, using a multimodal approach. Drug order entry personnel were specifically instructed on product selection using a pre-existing IV antibiotic selection chart (Appendix C) and start time for the next dose. The PIS-entered start time for an IV antibiotic must take into account any recent retrieval from ADCs by RNs to ensure that doses are not also made in CIVAS. Additionally, the PIS-selected product entry must
coincide with the distribution stream for that patient care unit. Entry into the PIS directing CIVAS preparation when a product is already stored and being accessed by RNs via ADC results in unneeded CIVAS preparation. Failure to follow standardized order entry procedures results in product and time waste.

To assess the success of the re-education strategy in reducing non-value-added time, the proportion of doses of the representative IV antibiotics entered into the PIS as per standardized procedure and waste in terms of cost of product returned unused and time were evaluated before and after education.

**Do**

The primary author (J.L.) provided education on standardized order entry procedures for IV antibiotics on Friday June 3, 2016 at pharmacist and pharmacy technician weekly meetings, via email notification, and by placing verbal and written reminders at the drug order entry desks. J.L. collected data on order entry appropriateness and waste before and after education. Twenty sequential orders for each of IV ampicillin 2 g, cefazolin 2 g, and piperacillin-tazobactam 3.375 g or 4.5 g were reviewed retrospectively to determine the appropriateness of entry into the PIS with respect to start time and distribution selection as defined by the pre-existing chart of IV antibiotics to guide product selection based on patient care unit and medication. The number of minibags for each of these antibiotics returned unused to Pharmacy Services during a one week period before and after education (May 19th-25th, 2016 and June 6th - 12th, 2016, respectively) was recorded on a daily basis at 1600 hours.

**Study**

Collected data was analyzed descriptively and then compared using appropriate statistical methods. Cost of product wasted, defined as returned to pharmacy unused, and associated labour cost, as determined using non-value-added times from value stream maps (Figure 1, 2,
3), were calculated for each of the before and after education periods and compared. Refer to completed PDSA Work Plan for a detailed description of statistical analysis methods (Appendix B).

**Act**

Findings were presented to the project stakeholder group and recommendations for subsequent actions and PDSA cycles were formulated on September 1, 2016.
RESULTS

Value Stream Mapping

Current state value stream mapping of the three IV antibiotic distribution streams occurred on December 18, 2015 by the stakeholder group. The total time per cycle for one unit (e.g., represented by one minibag of IV ampicillin) of the CIVAS stream was 67 minutes (Figure 1). The longest stream was Minibag via ADC (represented by cefazolin 2 grams) at 84 minutes (Figure 2) and the shortest was 62 minutes for the Vial via ADC stream (represented by piperacillin-tazobactam 3.375 or 4.5 grams) (Figure 3). Of these streams, the least amount of waste in terms of non-value-added (waste) and non-value-added (essential) time occurred in the Vial via ADC with 46 minutes (74% of total time). The most waste was associated with the CIVAS stream with 72 minutes (86% of total time) (Figure 4). Non-value-added (waste) time included product waiting at any stage of the process and checking for viable intact product returned that could be recycled. Non-value-added (essential) time included gathering and delivering IVs, loading product into ADCs, and final product double checks. Value-added time included drug order entry, gathering/picking supplies, and compounding process or activating by POC device.

The same number of operators is required in each stream, but the make-up is different. Vial via ADC is reliant on the nurses with 16.1% of total process time by the RN, compared to 1.5% of total time when distributed through the CIVAS stream and 1.2% through the Minibag via ADC stream.

There was more variability directly observed on the patient care units in the Vial via ADC stream. Variability included reconstitution by RN with syringe and vial due to lack of knowledge of Minibag Plus® activation, RN confusion on what format medication would be provided by Pharmacy Services and inconsistencies in maintaining the cold chain for CIVAS prepared items. The Vial via ADC stream relied on nursing staff to do IV admixing in an environment less
controlled than Pharmacy’s CIVAS room. Upon adhoc questioning during direct observation, nurses relayed that Minibag Plus® is not always available to them at time of need, and that sometimes reconstituting via vial and syringe is faster to dissolve piperacillin-tazobactam. Some reported that it only takes a few minutes to reconstitute piperacillin-tazobactam, while others stated that it could take up to 20 minutes.

**Opportunity Classification**

The stakeholders group met on March 21, 2016 and identified 13 opportunities for process improvement (Figure 5). Re-educating on standardized PIS drug order entry, redistribution of workload in IV room, changing the main IV batch label print time, limiting/standardizing the options available in the ADCs, and changing delivery cut-off time are the five opportunities that fell into the “implement” quadrant of the PICK chart.

**PDSA Cycle**

The improvement opportunity selected from the “implement” quadrant to educate pharmacy staff on standardized order entry procedures took place on Friday June 3, 2016 using a multimodal approach. An email was distributed to all pharmacy staff which was comprised of 34 Registered Pharmacists and 44 Regulated Pharmacy Technicians. There were 41% and 16% present during the education sessions at the pharmacist and pharmacy technician meetings, respectively.

Forty-one of the 60 orders screened before education and 39 of 60 orders screened after education were eligible for inclusion in the statistical analysis. Orders were excluded if there was no prior ADC entry on the PIS. There was no statistically significant change in the overall proportion of IV orders of each distribution stream (ampicillin, cefazolin, piperacillin-tazobactam) that had both the appropriate start time and distribution stream selection with 20/41 (48.8%) before and 18/39 (46.2%) after education (Figure 6). Similarly, the overall total proportion of
orders entered into the PIS with the appropriate start time was essentially unchanged [23/41 (56.1%) before and 24/39 (61.5%) after] as was the proportion entered with the appropriate distribution stream selection [35/41 (85.4%) before and 30/39 (76.9%) after]. The data breakdown for each individual distribution stream can be found in Figure 7.

The number of unused minibags of representative IV antibiotic returned to pharmacy pre- and post-intervention and associated resource costs are reported in Table 1. Labour costs were calculated using the average hourly wage for Regulated Pharmacy Technicians ($26.76/h) and for Registered Nurses ($36.95/h) based on the collective agreements between Kingston General Hospital and Public Service Employees Union and Ontario Nurses Association, respectively.\(^8,9\) Ampicillin returned to pharmacy increased by four bags (16.7%), representing 268 minutes of non-value-added time, which may be monetized to $126.52 of combined wasted product and time. Cefazolin waste increased by 14 bags (100%) or 1,176 minutes, equal to $392.67 waste of combined product and time. Piperacillin-tazobactam was the only one with a significant reduction in waste with a decrease of 16 bags (69.6%) or 992 minutes waste reduction of product and time waste by $465.76. However, it is important to note that the only piperacillin-tazobactam returned to pharmacy was the 2.25 g bags which follow a CIVAS distribution stream similar to that of ampicillin, as opposed to Vial via ADC. There was no statistically significant difference between either the overall number of wasted doses, or cost of waste, before and after intervention (Table 2).

Ad hoc staff feedback collected during the study conveyed a belief that technology is the driver of waste in a number of areas. For example, the majority of waste appeared to occur due to discontinuation of therapy or patient transfer to a unit with provision of product via a different distribution stream. During the Study portion of the PDSA, it was identified by staff that there is a dependence on the PIS to direct order entry (e.g., existence of an ADC icon is relied upon to determine the distribution stream, not the guidance chart). However, it was acknowledged that the ADC icon is unreliable, as it is not reflective of the distribution option if a patient has been
transferred on the medication from a unit with a different distribution stream. The net result can be that patient-specific CIVAS production even though the product is stocked on the unit. Nursing staff overrides the ADC to use a stock non-patient specific minibag or vial and the CIVAS prepared minibag is ultimately returned to pharmacy as waste. The second most frequently reported cause for waste was when a patient’s IV medication is discontinued. The actual timing of the final dose administration is often not known, largely due to an incorrect start time in PIS. When product is made in CIVAS despite the first dose being taken as a vial via ADC, an additional dose is ultimately prepared and distributed at the end of therapy. It is believed to be too time-consuming and challenging to determine how many doses are to be made and sent from CIVAS based on the current technology and processes when nursing staff simultaneously have access to and may be preparing doses on the patient care unit. For CIVAS prepared doses, an additional 24 hour supply can be made during the main batching process that occurs at 0700 hours daily in advance of notification of medication discontinuation. Together with an inaccurate start time, waste of a 24 hour or more supply may result. This was observed during the data collection period. Recommendations to decrease non-value-added time were made in the “Act” section of the PDSA Work Plan (Appendix B). Improved standardization of processes to reduce variability, specifically around PIS drug order entry, and limitation of distribution stream options for selection both in the PIS and for nursing on patient care units were proposed.
DISCUSSION

Defining the current processes of IV antimicrobial distribution at KGH, using LEAN methodology has been undertaken to improve current processes and support future decision-making.

Consistent with the seven wastes identified in health care in literature, the primary sources of waste identified in IV distribution at KGH include inventory (too many options for selection), defects (PIS setup, ADCs not showing orders until entered start time, product coring with POC, cold chain not maintained) and unnecessary processing (recycling, sending product that has already been accessed via ADC).

The percentage of value-added time in each stream appears to be low in proportion to the total time, but the proportions are in alignment with processes that have undergone value stream mapping. Focusing on waste reduction (non-value added time and processes – both essential and pure waste) will serve to increase the value-added proportion.

Due to the time constraints of the project and the ease of implementation, the opportunity selected, in an attempt to reduce non-value added resource use, was one which was within the control of the pharmacy department. In addition, review of standardized PIS drug order entry procedures with staff did not require a large change in procedure or workflow. It was anticipated that adherence would improve after staff education, leading to less variability. However, there was no improvement detected. Although this particular intervention was ineffective at reducing waste on its own, other factors contributing to waste of product and time were brought to light during the study, including faults in the current drug order entry process its self. These factors may include: too many distribution stream options available, lack of trust in the IV stream selection chart for direction and dependence on the PIS to direct order entry using the ADC icon status. In some instances, staff, recognizing the shortcomings of the current standardized procedures and ADC technology, purposefully did not ‘adhere’.
Some staff actively chose not to set an appropriate start time for the next dose, as profiling a later start time prevents nursing staff from viewing the active order on the ADC patient's medication list.

Total IV product waste was also not reduced as anticipated. This may be due to the fact that a substantial portion of the pharmacy returns could be attributed to discontinuation of drug orders and patient care unit transfers. ADC stock varies from one unit to another, and when patients are moved, the PIS does not update automatically to reflect the distribution stream for the new location. In addition, the orders entered and evaluated during the study periods did not precisely correspond with returns arising from the orders evaluated due to a lag time for effect. Product was also dependent upon the gathering of unused IVs and return to pharmacy, a process which is reported to lack consistency. Some pharmacy technicians checked patient care units for IVs to be returned, while others did not. While waste was overestimated, as some returned product may be recycled for use in a different patient, a portion of labor time is always deemed to be wasted.

Of all the IV orders screened, over half of the first doses were found to be accessed from the ADC by nursing staff without prior review by a pharmacist. The potential impact on patient safety, positive (timely patient administration of IV antibiotic when pharmacy is closed) or negative (inappropriate product selection), was not assessed. Based upon this finding and pharmacy practice standards, however, further process study in this area is warranted.

Implementation of an electronic or PIS generated medication administration record may be beneficial from both a patient safety and resource waste perspective, but implementation challenges exist. Direct observations also revealed other safety concerns, including lack of standardization of responsibility for promptly refrigerating IVs delivered via pneumatic tube, which results in IVs sitting out for an unknown period of time. Lack of knowledge regarding the existence or location of POC activation supplies was a potential contributor to reconstitution of vials by RN using a syringe instead of MiniBag Plus®. Even with MiniBag Plus® use,
inconsistencies occurred during nursing preparation from continuous shaking to letting activated sit to dissolve, resulting in a wide range of reconstitution times. The location of reconstitution by RN staff also varied; some mixed in the medication room, while others mixed in other areas of the patient care unit including corridors and patient rooms.

A potentially high favorable impact opportunity from a patient safety perspective, albeit at a high resource outlay is the expanded use of commercially-manufactured IV antibiotics within the KGH IV antibiotic distribution process. Such an expansion may offer several benefits including enhanced compliance with applicable standards, reliable product, labor resource use efficiencies, and extended beyond use dating. However, increased acquisition cost, potential for excessive inventory, and lack of flexibility for patient-specific formulations continue to be significant limiting factors. Continued but expanded focus on reducing waste and variability within the current IV distribution streams may be a better use of institutional resources.

It should be noted that this study did not address missing IV medications because there was a concurrent project looking at this issue and the steps for managing a missing medication have already been outlined in a Professional Practice Exchange Newsletter from September 23, 2015. In addition, evaluation of appropriate evidence-based IV antibiotic prescribing practices was not within the scope of this project.

A common theme of the observations and findings in the root cause analysis in the PDSA Work Plan (Appendix B) was that it is difficult to follow current standardized procedures due the complexity and evolving nature of the distribution process. For example, in PIS drug order entry, there are many product options from which to select. When referring to the IV Antibiotic Selection Chart, it takes longer to use this external source for information (outside of the PIS) than with PIS (ADC icon). Discrepancies in the chart exist due to lack of timely updating to reflect recent ADC changes, decreasing trust in the chart for direction. The time and focus that is spent on identifying the correct distribution stream could be better used elsewhere, such as identifying appropriateness or duplication of therapy.
CONCLUSION and RECOMMENDATIONS

This has been the first project to outline the distribution process for IV antibiotics at KGH since the implementation of ADCs. LEAN methodology, particularly the value stream mapping exercise, was useful to scrutinize the current state of IV antibiotic distribution. Pharmacy stakeholders were able to identify several opportunities to improve standardization of KGH's IV antibiotic PIS drug order entry and distribution processes. Recommendations for future projects include PDSA cycling of one or more of the aforementioned areas of variability and engaging nurse stakeholders to expand IV distribution process standardization to the patient care unit. Reducing variability will, in turn, reduce non-value added time (waste) by increasing trust in the distribution system allowing pharmacists, pharmacy technicians and nurses to be more efficient with their time and focus on patient safety and quality of care.
ACKNOWLEDGEMENTS

The stakeholder group:

● Pui Yu Lau, RPh, Drug Distribution Manager, Pharmacy Services;
● Susan McIlroy, RN, Patient Relations and Quality Advisor Patient Safety, Quality & Risk Team, Kingston General Hospital;
● Linda Brunet, RPhT, Senior IV Pharmacy Technician, Pharmacy Services;
● Annie Greer, RPhT, ADC Superuser Pharmacy Technician, Pharmacy Services;
● Maria Marchese, RPh, Pharmacy Resident, Pharmacy Services; and
● Chantel Duncan, Pharmacy Student, Pharmacy Services

for their contributions to value stream mapping and opportunity identification, and

● Bonnie Ralph, RPh, Coordinator Pharmacy Residency Program, Pharmacy Services, for her advisory role
REFERENCES


8. Collective agreement between Ontario Public Service Employees Union on behalf of its Local 444 and The Board of Governors of Kingston General Hospital. April 1, 20014 – March 31, 2016.

**Figure 1.** Current state value stream map of traditional patient-specific admixture via Central Intravenous Admixture Service (CIVAS) distribution, represented by all doses of IV ampicillin.
Figure 2. Current state value stream map of minibag via automated dispensing cabinet (ADC) in ready-to-administer, non-patient-specific IV admixture distribution, represented by IV cefazolin 2 grams.
Figure 3. Current state value stream map of vial distribution in automated dispensing cabinet (ADC) for reconstitution using point-of-care (POC) activation device (Minibag Plus®), represented by IV piperacillin-tazobactam 3.375 grams and 4.5 grams.
Figure 4. Classification of Value Stream Map process steps as value-added or waste, in terms of time per cycle, where the cycle starts at pharmacy information system (PIS) drug order entry and follows product until ready to administer, and percentage of total time. CIVAS = Central Intravenous Admixture Service. ADC = automated dispensing cabinet. POC = point-of-care (MiniBag Plus©)
Figure 5. Possible, Implement, Challenge, Kibosh (PICK) chart of identified opportunities to improve IV antibiotic distribution process from patient perspective. Circle indicates chosen opportunity.
Figure 6. Appropriateness of pharmacy information system order entry start time and distribution stream (product) selection before and after education, by representative antibiotic and overall. All p-values were greater than 0.05, indicating no statistically significant change.
Figure 7. Orders for antibiotics representing distribution streams, before (Pre) and after (Post) education, according to inclusion and exclusion criteria for adherence to drug order entry standardized procedures.
Table 1. Unused minibags of representative IV antibiotic returned to pharmacy before (pre) and after (post) intervention, according to volume and cost (labor plus drug acquisition).

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<th>Cost of Unused Minibags</th>
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<td><strong>Piperacillin-tazobactam 2.25 g</strong></td>
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<td>7</td>
<td>$29.11 $3.30 $2.53 $23.28</td>
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*Drug acquisition cost of 2 grams based on 10 gram vial

**Piperacillin-tazobactam 2.25 grams is distributed via CIVAS patient-specific (on-demand) stream**
Table 2. Comparison of Unused (Wasted) IV Antibiotic Minibags during Seven-Day Period before (Pre) and after (Post) Education Intervention

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<th>Variable</th>
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<td><strong>Total Volume of wasted minibags (7-day period)</strong></td>
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<td>Pre-intervention</td>
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<td>Post-intervention</td>
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<td><strong>Total Cost (Labor and Product) of wasted doses (7-day period)</strong></td>
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<td>Pre-intervention</td>
<td>$601.33 ($199.79 - $1002.87)</td>
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<td>Post-intervention</td>
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APPENDICES

Appendix A. Completed Project Management Plan
Appendix B. Completed Plan-Do-Study-Act Work Plan
Appendix C. IV Antibiotic Product Selection Chart (September 2015 Version)