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Improving Small-Volume Antibiotic Administration for Surgical Prophylaxis

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**Abstract**

**Background:** Small-volume IV antibiotics are commonly administered for surgical prophylaxis, but no clear policy on administration method exists, leading to wide variation in anesthesia provider practice at a large academic medical center. Administration via a secondary tubing set is the recommended practice to minimize significant medication losses which could lead to poor patient outcomes. This large academic medical center performed below the national benchmark for one of these outcomes–surgical site infections.

**Goals and Objectives:** Objectives of this project included eliminating a potential systematic shortcoming in the administration of prophylactic antibiotics. The goal was to increase the use of secondary tubing techniques for small-volume antibiotics in order to reduce medication losses and waste in administration sets. The expected outcome of this project was 100% provider adoption of the use of secondary tubing for all small-volume antibiotic administration.

**Design and Methods:** The pre-intervention phase involved observation of provider practices and measurements of medication waste and was followed by an educational intervention for nurse anesthetists on the new policy and best practices for administration of small-volume antibiotics. Following the education, three PDSA cycles were run to evaluate changes in practice and reductions in medication waste over a six-week period. Mean volumes were evaluated using two sample t-tests.

**Results:** The most common pre-intervention tubing method used was primary tubing (52%), and the most common post-intervention tubing method was secondary tubing (93%). Mean dead volume for these methods were 13.45mL and 0.79mL (p<0.01) respectively. Statistically significant (p < 0.01) decreases in dead volumes and percentage of medication lost were observed from all pre-intervention methods to post-intervention.
Conclusions: System and person changes were made to foster consistent practice and to potentially prevent poor patient outcomes in the operating rooms at the project site. Providers benefited from the educational intervention by strengthening their clinical practices, and the proposed project intervention required minimal upfront cost with tremendous upside both for cost-reduction and patient well-being.
Introduction

In recent years, the reduction of surgical site infections and antimicrobial-resistant organisms has become a significant focus of healthcare institutions and organizations throughout the country due to a 2009 federal law requiring state action plans for the prevention of healthcare acquired infections (Health.gov, 2020). The current project aimed to address one factor related to this effort in an attempt to improve patient care delivery and outcomes. The issue of dead-volume medication losses (i.e. medication left in the intravenous tubing set after administration) has not been adequately studied or addressed in the literature or clinical practice. However, this should be of primary concern to researchers and clinicians in the perioperative setting. Complete antibiotic dosing for surgical prophylaxis was the primary concern of this project. An educational intervention for Certified Registered Nurse Anesthetists (CRNAs) on the best practices for complete administration of small-volume antibiotics helped ensure that patients at this large academic medical center received appropriate, timely, and cost-effective care by reducing administration errors at the person and system levels.

Background

Nurses play an integral role in the health and safety of patients throughout the hospital setting and are responsible for taking an active role in implementing evidence-based practice, especially in the area of antibiotic administration and antimicrobial resistance (Ellen et al., 2017). Intravenous (IV) antibiotics for surgical prophylaxis include any antibiotics given preoperatively for the purpose of preventing or reducing the risk of postoperative surgical site infections (Crader & Varacallo, 2021). CRNAs administer these IV medications routinely in the operating room,
and a number of these medications are provided in small-volume IV bags that necessitate the use of IV tubing administration sets.

Small-volume IV infusions are considered infusions with a volume of 100mL or less, usually 50mL or 100mL (American Society of Health System Pharmacists, 2018). Some providers use primary gravity infusion sets or primary infusion sets through a pump, while others use the secondary or intravenous piggy-back method (IVPB) to deliver the medications. Individual providers may choose to use primary tubing sets due to the easy and quick access to tubing in the supply carts and increased familiarity with the technique. The Infusion Nurses Society, however, found that IVPB administration of small-volume antibiotics via a secondary infusion set with a continuous infusion of fluids consistently resulted in the maximal dosage of antibiotic being administered, and thus to be the most efficient way to prevent underdosing compared to primary gravity or pump administration (Harding et al, 2020). Chronically underdosing surgical patients by large amounts could have significant clinical implications for the incidence of surgical site infections (SSI) and the development of drug-resistant bacteria (Bratzler et al., 2013; Olofsson & Cars, 2007; Roberts et al., 2008).

**Problem Statement**

Previously, a variety of practices were being used by CRNAs to administer small-volume antibiotics in the operating rooms at this large academic medical center, resulting in significant medication losses which potentially put patients at risk for adverse surgical outcomes. The current project quantified this phenomenon through an observation of clinical practices and provided education to CRNAs on current best practices for patient safety and quality of care. This educational intervention could have far reaching impacts for the institution and its patients due to the frequency of antibiotic use in the operative setting.
Significance/Organizational Gap

Intravenous antibiotics for surgical prophylaxis are recommended for nearly all surgical cases (Bratzler et al., 2013), and thus are given millions of times per year in the United States (Steiner et al., 2020). Any variable relating to antibiotic administration, especially dosing, could affect millions of surgical patients. Underdosing of IV antibiotics could result in an inability to achieve therapeutic drug concentrations, which are required to effectively kill microbes and prevent the proliferation of antimicrobial-resistant bacteria (AMR), theoretically resulting in poorer patient outcomes (Olofsson & Cars, 2007; Roberts et al., 2008). The use of primary tubing sets by many providers, without concomitant use of flushing the tubing set or extracting dead volumes, could result in significant underdosing of prophylactic antibiotics in the perioperative setting. Currently, there is no definitive policy on administering small-volume antibiotics in the operating room at this large academic medical center. Primary infusion sets given via pump could result in a loss of 4.2-11.5% of medication for 100mL bags and 11.9-47.5% of medication for 50mL bags, while primary gravity infusion sets could result in a loss of 21.0% in 50mL medications and 10.8% in 100mL medications. (Bolla et al., 2020; Cooper et al., 2018; Harding et al., 2020; Plagge et al., 2010; Rout et al., 2019).

Reducing SSIs in the surgical population can improve patient outcomes. SSIs are associated with increases in morbidity and extend hospital length of stay by between 2.1 and 54 days, while decreasing quality of life (Badia et al., 2017; Patient Safety Network, 2019). SSIs also carry a 3% mortality rate, cost hospitals $3.3 billion annually, and are the leading cause of readmission after a surgical procedure (National Healthcare Safety Network, 2021; Patient Safety Network, 2019). Currently, this medical center is performing worse (1.637) than the national standardized infection ratio benchmark of 1.000 for SSIs from colon surgery which is
one of the two surgical procedures reported to the United States Centers for Medicare and Medicaid Services for quality and safety assessment regarding SSIs (Medicare.gov, 2021). Additionally, AMR is estimated to have cost the United States $20 billion in additional healthcare costs plus another $35 billion in lost productivity based on a 2013 study (Centers for Disease Control and Prevention, 2013). The potential reduction of these negative outcomes through complete antibiotic administration requires consistent practice among providers. CRNAs in the operating rooms at the project site administer hundreds of antibiotics weekly and thus have a drastic impact on antimicrobial administration (Wolfe, January 2021).

**PICOT**

At a large academic medical center surgical patients frequently receive small-volume antibiotics for their procedures, and observed practice varied between providers. Therefore, the question this project attempted to answer is, in the operating rooms at a large academic medical center, does an educational intervention for CRNAs (P) on the consistent use of secondary infusion sets for small-volume IV antibiotics (I) compared to primary line use and other techniques (C) reduce dead-volume medication waste (O) over a six-week period (T)?

**Review of Literature**

**Search Terms**

To answer this clinical question, a literature review of related terms was performed. Searches focused on the significance of surgical site infections, antimicrobial resistance, and the guidelines surrounding small-volume antibiotic administration. Initially, the CDC website was investigated for surgical site infection data and costs, with information provided by the National
Healthcare Safety Network. Other sources of data for surgical site infection included the Agency for Healthcare Research and Quality. In addition to simple Google searches for this information, Google Scholar, PubMed, Lippincott Nursing Center, CINAHL and Medline were queried for related articles. Search years were from 2010-2020 except when there was a dearth of results in certain specific CINAHL searches.

General search terms related to practices included “small-volume infusion,” “flushing guidance,” and “flushing infusion sets” among others, with subject headings (MeSH) of “Infusion/intravenous standards,” “evidence-based practice,” “nursing process”. General search terms related to significance and consequences of antimicrobial dosing included “antibiotic resistance,” “selection of antibiotic resistance,” and related terms with MeSH headings of “drug resistance bacterial,” “anti-bacterial agents,” and “nursing role”. Filters for these searches also included adult population, English language, and peer reviewed journals. Because of the limited amount of data and investigation into small-volume tubing-related waste of antibiotics, search results were limited but very specific in nature. No thorough randomized control trials or quasi-experimental studies have been performed on tubing-related losses and their impact on clinical outcomes as there are many confounding variables affecting the occurrence of surgical site infections. Additionally, it would be unethical to intentionally underdose patients and funding for such research would be difficult to obtain, especially when there are existing methods to fully administer ordered doses (Clark, 2020) The current literature on dosing of small-volume IV antibiotics for the prevention of surgical site infections and resistant bacteria is scant. Guidance and clinical implications, however, can be drawn from existing data and knowledge of antibiotic pharmacokinetics, indications for administration, and common errors.
**Antibiotic Prophylactic Dosing**

Onufrak et al. (2016) identified that, for certain antibiotics, especially aminoglycosides and fluoroquinolones, peak concentration is the determining factor in treatment efficacy and not duration of treatment. Therefore, the importance of initial dosing that achieves appropriately high concentrations of drug at the tissue level which are at least 8-10x the minimum inhibitory concentration (MIC) level to prevent microbial growth and proliferation is recommended. Gentamicin and ciprofloxacin are two antibiotics in these classes which can be administered in small-volume concentrations and are commonly administered at this large academic medical center (Wolfe, January 2021). Roberts et al. (2014) assessed the literature related to dosing of antibiotics in critically ill patients and found that individualized, specific patient dosing based on a number of clinical factors is vital to the administration of prophylactic antibiotics, particularly in the critically ill population. Therefore, dosing can directly impact the efficacy of treatment. Patients with higher acuity levels–those with “altered fluid status, microvascular failure, [deranged] serum albumin concentrations as well as altered renal and hepatic function”–often require higher MIC levels to achieve therapeutic results (Roberts et al., 2014, p 499). Martinez et al. (2012) also noted that suboptimal or subtherapeutic levels of antibiotics can not only fail to achieve treatment goals, but also lead to increased selection for drug resistant bacteria. The authors postulated that drug exposure achieved during the first administration of an antibiotic medication is the most important factor in decreasing the risk of developing a resistant infection.

**Indications**

Small-volume antibiotics are often recommended for particular types of surgical procedures. In Bratzler et al. (2013), the American Society of Health-System Pharmacists, the
Infectious Diseases Society of America, the Surgical Infection Society, and the Society for Healthcare Epidemiology of America synthesized a series of recommendations relating to the administration of prophylactic surgical antibiotics for perioperative patients. For clean urologic procedures with risk for postoperative infection, clean-contaminated urologic procedures, small bowel obstruction procedures, colorectal, and gynecologic procedures, various combinations of small-volume antibiotics such as metronidazole, ciprofloxacin, clindamycin, gentamicin, or ampicillin-sulbactam are recommended as single or minimal dose prophylaxis for the prevention of surgical site infection. These multi-organizational recommendations for small-volume antibiotic use in gastrointestinal, genitourinary, and gynecologic procedures pointed to the operating rooms at this large academic medical center as a high yield location for the assessment of small-volume antibiotic administration methods.

**Errors in Administration**

Small-volume antibiotics carry with them the risk of a greater percentage of drug loss when administered with the same infusion methods as larger volume antibiotics simply as a ratio of total volume to administration set volume. When administering these medications, perioperative CRNAs run the same risk of medication-related errors as the rest of the hospital. Medication error types and frequencies were reviewed by Wolf & Hughes (2019); the authors used a mixed methods approach to synthesize data from the Institute for Safe Medication Practices’ (ISMP) medication safety report involving infusion medications and found that administration errors were the most common type of errors reported compared to dispensing, prescribing, and other phases of medication use. Improper dosing was the most frequent mistake in the administration process most often resulting from knowledge-based mistakes and planning failures. Lack of knowledge of dead-volume losses could be one contributor. Additionally, IV
bag overfilling is an area of confusion that may be leading to knowledge-based mistakes. According to the ISMP, medication and diluent overflow vary depending on the manufacturing method and the pharmacy or provider reconstitution method, and if that method is not clearly described on the medication label, CRNAs cannot assume that the overfill in the IV bag accounts for the dead-space losses in the tubing set, especially with intermittent single dose medication which need to be completely administered (2013). The perioperative clinical pharmacy specialist at this large academic medical institution confirmed that overfilling is not standardized and varies from lot to lot; but overfill is usually less than tubing set volume, therefore the entire medication bag should be infused to the patient with each administration (Wolfe, June 2021). Planning and knowledge from education of best practices appears to be an important factor in reducing infusion-related errors such as underdosing. In the case of small-volume IV antibiotics, these errors can cause substantial risk to the patient. Because of this, the Institute for Safe Medication Practices identified small-volume medication loss in primary administration sets as a top 10 medication hazard in 2020 that can be improved by the use of secondary tubing through education of care providers (2020; 2021).

Both theoretical and clinical evidence points to a significant loss of medication in administration sets caused by failure to fully administer or use appropriate administration sets for small-volume medications such as antibiotics. Bolla et al. (2020), used a theoretical 70kg patient with common IV infusion sets found in clinical practice in the UK National Health Service hospital system to calculate potential losses of drug due to dead volume. Of the 39 medications tested, losses ranged from 2% to 33% with 26 of the 39 medications resulting in a 10% or greater drug loss. This study provides mathematical support for addressing the problem of small-volume losses without proper administration technique and guidance. In Cooper et al. (2018), drug waste
from small-volume medications was assessed at a large UK teaching hospital. Failure to administer full doses exceed 90% and 61% for primary gravity and pump administration sets respectively. This practice resulted in about 21% of drug volumes being wasted and not administered to the patient. Plagge et al. (2010) also assessed drug losses at a university hospital along with a laboratory setting and found that between 15% and 47% of drug volumes in the laboratory setting were wasted depending on when the infusions were stopped. In the clinical setting there were less drastic losses, however, dead space wastes were between 14% and 20% for 100mL infusions and 24% and 32% for 50mL infusions.

**Evidence-Based Practice: Verification of Chosen Option**

In order to address the issue of small-volume drug wasting, the Infusion Nurses Society published two articles in their Journal of Infusion Nursing which described methods for administration of small volume antibiotics, calculated using empirical laboratory data with comparative clinical observation. Harding et al. (2020) identified that administration using a secondary piggyback administration set connected to a continuous infusion results in the smallest amount of drug volume and concentration loss due to dead space when compared to primary gravity and pump infusion sets and secondary sets connected to intermittent fluid infusions. Thoele et al. (2018) additionally demonstrated the most appropriate method for delivering complete antibiotic doses. The authors’ comparative analysis of backflushing and pinch methods for secondary sets resulted in near total administration of antibiotic dosage when the primary arm of the administration set was pinched closed towards the end of a secondary administration to allow the remaining volume of medication to flow out of the secondary set into the primary set before releasing the pinch and continuing the primary infusion. This method resulted in “precision and consistency, as well as the greatest accuracy in drug delivery” (Thoele et al.,
Although the pinch method resulted in a marginal increase in provider time (about 2 minutes), a more complete dose was administered to the patient compared to a backflushing technique. While a practice change from primary to secondary tubing was the ultimate intervention of this project to reduce dead volumes, the use of the pinch method provided additional decreases in medication waste when employed by CRNAs toward the end of antibiotic administration.

Conclusions

The evidence on antibiotic dosing emphasizes the importance of patients receiving full doses of antibiotics to prevent infection and reduce the likelihood of developing drug resistant bacterial strains. Perioperative CRNAs at this large academic medical center frequently administer small-volume antibiotics and run the risk of underdosing their patients through lack of clinical awareness of the dead volume medication they are omitting. Through common but unintended dosing errors, providers introduce the risk of harming their patients and providing suboptimal therapies with potentially significant drug losses. Clark (2020) argues that intentionally using a system that does not fully administer ordered doses constitutes off-label use and could be considered professional negligence, therefore it was important to educate providers on more effective methods of administration. The Infusion Nurses Society and the Institute for Safe Medication Practices have provided guidance on the administration of small-volume infusions that could drastically reduce the issue addressed by this project. By implementing this minor practice change, one variable in the correlative chain of surgical site infection and drug resistant bacteria was ameliorated to benefit the patient population.
Theoretical Framework: Evidence Based Practice Model

Reason’s (2000) theory on human error can be used to describe these errors in medication administration. This model has been called the Swiss cheese model as it describes how multiple holes in a system’s defenses must line up to allow an error to occur (Appendix A). There are two divergent but interrelated methods of looking at medical errors, the person approach and the system approach. The person approach focuses on individual failures leading to error while the systems approach focuses on errors as a consequence of organizational policies, procedures, working conditions, etc. (Reason, 2000). One example of a system error was the lack of clear policy relating to small-volume antibiotic administration in the operating room. Oftentimes system errors and person errors must line up at the same time for the collective faults to reach the patient and potentially cause harm. Person errors such as lapses or slips by the CRNA not identifying dead-space volumes can result in the unintended consequence of a patient not receiving the full dosage of medication (Reason, 1990). This framework helped guide the project towards closing holes in the system to reduce the likelihood of error.

Goals, Objectives, and Expected Outcomes

The objective of the current project was to eliminate a potential system hole and possible causal factor of surgical site infections and antimicrobial resistance. The goal was to increase the use of secondary tubing techniques for small-volume antibiotic administration in order to reduce the volume of medication left in tubing administration sets, and thus medication waste. By adopting this practice, CRNAs improved patient care delivery in the perioperative period. According to the Institute of Medicine (IOM) (2001), "care should not vary illogically from clinician to clinician or from place to place" (p. 8). By addressing this practice gap and
standardizing practice in the operating rooms at the project site, CRNAs provided consistent care to every patient. The IOM's six domains (Appendix B) of quality can all be addressed by this project moving forward. Meeting all of these aims was a necessity in order to implement a project that will have sustainable and beneficial outcomes for patients. Expected outcomes of this project include 100% provider adoption of the use of secondary tubing for all small-volume antibiotic administrations at the close of the project.

**Project Design**

The project involved a best-practice educational intervention for nurse anesthetists for small-volume antibiotics administration. Prior to the education, antibiotic administrations were observed and IV tubing sets attached to antibiotics were collected for sampling and volume calculations for a four-week period in order to establish a baseline of wasted medication and provider practices. The initial collection was followed by multiple individual education sessions throughout a two-week period on varying days of the week to ensure each shift and CRNA schedule are covered. The 5–10-minute education session included a brief explanation of current antibiotic prophylactic guidelines and the importance of SSI and AMR prevention. The on-site evidence of administration practices from the previous sampling was also presented, and the proposed practice change (Appendix C) was then discussed with the accompanying recommendations from the Journal of Infusion Nursing and the Institute for Safe Medication Practices. The CRNAs had the scope of the project explained to them at this time, including the post-intervention data collection plan. All staff questions were answered at this time. Continuing dead-volume measurements and technique assessments were collected over the next six-week period in two-week PDSA intervals and were analyzed at the conclusion of the project to demonstrate sustained adoption of the practice change.
Project Site and Population

Parkview Tower is on the campus of Barnes-Jewish Hospital which is a large academic medical institution in an urban setting that performs over 42,000 surgical cases per year for patients with varying acuity levels (Barnes-Jewish Hospital, 2019). The twelve operating rooms at this site commonly house gastrointestinal, genitourinary, and gynecological surgeries, and were selected as a site of study because these surgeries frequently employ the use of small-volume IV antibiotics. The surgical cases in these operating rooms involve minor and major procedures with outpatient and inpatient designations. All 18 CRNAs at this site working in cases involving the administration of small-volume IV antibiotics during the perioperative period were recruited for this project. Some CRNAs worked exclusively at this location while other CRNAs rotated through this location, so the goal was to educate all 18 CRNAs who may find themselves working in these operating rooms during the project timeframe. These CRNAs represented a range of experience levels and tenure at this institution. Provider demographic data, including age and years of experience at the institution, were obtained from the Director and the Assistant Director of CRNA activities. Recruitment of CRNA participants was achieved through use of email and in-person conversations. All 18 CRNAs were educated on the practice change via written email, while 14 CRNAs were able to receive individual in-person or over the phone education. A convenience sample was obtained for this population based on daily assignments. A total of 7 CRNAs were observed in the pre-intervention phase and 9 CRNAs were observed in the post-intervention phase. In total, 11 different providers were observed for this project, all of which received the in-person or over the phone educational intervention. The age and years of experience at the medical center of pre-intervention and each post intervention PDSA cycle groups of CRNAs were analyzed and are depicted in Appendix D Table 2. The pre-
intervention observations had a mean age of 39.48 and mean years of experience at the medical center of 8.66. The post-intervention observations had a mean age of 50.14 and mean years of experience of 10.46. Years of provider experience at the medical center were not statistically different (p=0.37) for observations, but there was a significant difference in provider age (p<0.01). However, the age of providers pre and post was not significantly different (p=0.42).

**Setting Facilitators and Barriers**

The project design was well-received by the institution for a number of reasons. Moran et al. (2020), describes an appropriate practice setting for the clinical DNP project as one that aligns with the project’s aims and has strong academic-practice ties with the educational institution. Barnes Jewish Hospital (BJH) is a large academic medical institution with a Magnet® designation held for the last several years and a strong partnership with Goldfarb School of Nursing. According to the American Nurse Credentialing Center (2020), a Magnet® hospital must promote “new knowledge, innovation, and improvements” to nursing practice by restructuring and redesigning care based on the latest evidence for effective nursing care (para. 11). Based on the current evidence for secondary tubing choice and complete administration of small-volume intravenous antibiotics, a change in practice was indicated at BJH in the Parkview Tower operating rooms for surgical procedures. Moving forward with the project involved a careful assessment of its strengths and weaknesses. A SWOT analysis (i.e. an assessment of strengths, weaknesses, opportunities, and threats) of the institution revealed the contributing and inhibiting factors relating to the success of the project from development through implementation.

The central strengths of the project were that the practice change was simple and filled a gap in evidence-based practice that was currently not filled with a unifying practice guideline for
administering antibiotics in the perioperative timeframe by anesthesia providers. There was previously wide variation in a commonly performed clinical practice, and the institution promotes practice improvement, consistency and quality of care. The weaknesses of the project included the lack of strong practice guidelines by a national anesthesia organization. The practice also had some inherent cost involved and required multiple separate departments to change or approve practices. Other institutions previously promoted the practice change of this project including one within the BJH group. Additionally, the cost was mitigated and the change in practice was minute.

The opportunities related to the project included an educational institution which promotes evidence-based practice, continuing provider education, and direct provider acceptance of the project. The project also offered the chance for patient care and outcomes improvements. The threats to the project included mass acceptance of the project by multiple disciplines and unit management as it required some additional cost and time. During a currently ongoing pandemic, there was also the threat of supply shortages which could have impacted the feasibility of the project. These threats were manageable as the practice change was not drastic, and the effects of the pandemic were being aggressively resolved with the mass administration of vaccines and resumption of supply lines.

The operating rooms at Parkview Tower were ready to accept and implement quality improvement and practice change initiatives into clinical practice. The early stakeholder shared ownership by active CRNAs and pharmacists at the institution was promising for the progress of the project. Hospital and clinical management and administration were involved early and continuously throughout the project to ensure effective supply planning and practice implementation. With continued interest and approval from the identified stakeholders, the
strengths of the project provided the opportunity to improve practice at the institution in light of the apparent threats.

Methods

Measurement Instruments

Data collected for each observed medication administration included: case type, medication, volume, concentration, type of tubing set used (Appendix D Tables 3 & 4), and volume left in the set after administration. Observed and calculated outcome measures included total dead volume and percentage of antibiotic waste per administration. Because these outcome measures were the result of a practice change, the process measures included provider practice, such as the number of times a secondary set was used and the percentage of times a secondary set was used compared to total administrations observed. Balancing measures which may have affected practice implementation included daily availability of secondary tubing in each anesthesia supply cart and availability of secondary tubing in the anesthesia supply room, which was assessed at the beginning of each day prior to the start of the first case.

Prior to each day of observation, the electronic medical record (EMR) was used as a tool to identify surgical cases which used small-volume antibiotics. The daily surgery schedule tab was accessed to distinguish cases identified by Bratzler et al. (2013) as cases with indications for small-volume antibiotics. This tab provided case type and CRNA assignments, therefore accessing individual patient charts was limited to the orders tab when antibiotic choice was known to vary by surgeon preference. When a limited number of cases were identified the day prior to observation, the EMR surgery schedule was accessed on the day of observation to note any add-on cases.
On the day of observation, a questionnaire (Appendix E) created for this project was used to collect data on each administration. Sampling of tubing was performed by using 20mL syringes obtained from the anesthesia supply room to pull medication from the most distal port on the IV tubing. The sampling was performed out of view of the provider during the pre-intervention phase.

**Data Collection Procedure**

Data collection was performed in three phases, pre-intervention, intervention, and post-intervention. In order to complete the stated goals of this project, pre- and post-intervention data were obtained to quantify the impact of the proposed practice change. A two-week Plan Do Study Act (PDSA) style model was used to guide this project (Institute for Healthcare Improvement, 2021a). For the pre-intervention phase, which included the four weeks prior to the educational intervention due to low case numbers in the first two weeks, sampling occurred in Parkview Tower two times per week on Mondays and Tuesdays. These days were selected for their high caseloads and availability of the observer. Each week, the BJH EMR was monitored to identify operative cases with indications for small-volume antibiotics that could be used for data collection on the observational days. Due to low case numbers and observations, 200mL IV antibiotic bag administrations were also collected to obtain baseline provider practice for administering IV antibiotic bags. Once all of the potential antibiotic administrations were identified for each day, the CRNAs for each case were notified that their antibiotic administration would be observed and to not discard their administration paraphernalia after use. Because many of these administrations took place during a short time window, as multiple cases were taking place simultaneously, if an administration was not able to be directly observed, the CRNA was interviewed about their administration technique and the administration set was
collected for measurement. Data collected from these antibiotic administrations was recorded on a paper questionnaire (Appendix E) and entered into an Excel spreadsheet stored on a secure drive for analysis prior to the educational intervention phase. In order to maintain blinding of participants during the pre-intervention phase, the questionnaire contained extraneous questions related to the entire administration process, and dead volume calculations were done out of sight of the CRNA. Additionally, the supply room and anesthesia supply carts were inspected to identify whether or not secondary tubing was available to providers at these locations. During each observational day of the pre-intervention phase, secondary tubing was not on par in either location for the providers to use.

During the educational intervention phase, information was presented to Parkview Tower CRNAs via email and by a PDF flyer (Appendix F) posted in the breakroom. The flyer presented background evidence of the problem being addressed and data collected from the four weeks of prior observation and documentation. Following the data presentation, the best practice for small-volume administration suggested by the Institute for Safe Medication Practices and the Infusion Nurses Society (Harding et al., 2020; Thoele et al., 2018; Institute for Safe Medication Practices, 2020) was introduced with reminders of common errors to avoid. The flyer was also posted in the CRNA breakroom. The practice change did not involve a new technique or skill to be learned by providers, therefore the education mainly involved empirical support for the practice change. This educational tool presented peer-reviewed evidence and reports with practice guidance from internationally recognized healthcare practice organizations. During this phase, CRNAs were individually asked two open-ended questions either in-person or over the phone, one about their current technique for administering small volume antibiotics—primary pump, primary gravity, or secondary administration sets—to direct education towards current
methods. CRNAs were then individually educated on the practice change. The CRNAs were also asked what barriers, if any, they foresaw in implementing this new practice. No significant barriers or unaddressed variables were identified by the providers. During this phase, secondary tubing was put on par in the anesthesia supply room and the supply carts in coordination with the lead anesthesia technician.

Post-intervention volume sampling of tubing and method analysis from patient cases was performed using the same methodology as the pre-intervention phase without the questionnaire in Appendix E. Four of the post-intervention observations were done with photographic evidence and provider interviews after administration when direct observation was not feasible with no observer collection of tubing. This phase consisted of three separate PDSA cycles, PDSA 1, PDSA 2, and PDSA 3, each in two-week increments for a total of six weeks of observation, analysis, and action. Each two-week data collection was entered into the secured Excel sheet and analyzed to find areas for improvement for the next cycle. At the end of each cycle, each CRNA was asked again about their current practice technique for small volume antibiotics and asked if any new barriers had been identified. After the first PDSA cycle, one issue arose involving the administration of Unasyn via secondary tubing, which was remedied by educating all CRNAs via email and in-person education on the importance of opening the vent on the drip chamber prior to administration. No other significant issues involving the practice change were identified during this phase. At each observational day, secondary tubing was made available to the providers in the supply room and in the anesthesia supply carts. Following the post-intervention phase, data from each phase of the project was analyzed together and the findings are presented in this paper.
Data Analysis

Descriptive and inferential statistics were used through the SPSS Statistics 28 program with the assistance of a statistician provided by Barnes-Jewish College. Data was collected for four independent groups of CRNAs – one pre-intervention and three post-intervention cycles (PDSA 1, PDSA 2, PDSA 3). The independent variable for this project was the educational intervention and the dependent variable was dead volumes from antibiotic bags and percentage of volume lost. Descriptive variables to be collected were CRNA age, years of experience at the medical center, and primary or secondary tubing set used. A two-sample t-test was used to compare the groups’ dead volumes and percentage loss in pre- and each post-intervention cycle. To assess descriptive variables, CRNA age and years of experience means along with percentage of secondary tubing use was calculated for each group. Statistical differences between groups were analyzed using t-tests for age and years of experience. A two-sample t-test was also used to analyze the effect of the most common tubing administration method pre-intervention with the most common tubing administration method post-intervention (primary vs. secondary tubing). The alpha level was set at <.01 to achieve a 99% confidence level for each test.

Timeline

Appendix G delineates the timeline for the project from approval through dissemination of results. Initial approval was obtained in September of 2021, followed closely by recruitment and initial data collection in October. In the subsequent month, educational meetings took place to educate all CRNAs including leadership. For the next six weeks, post-educational data collection was performed at two-week intervals for a total of three cycles. In December 2021 and January 2022 data analysis took place, with the plan of disseminating results and findings soon after.
Results

Significant reduction in dead volumes and percentage of medication loss were observed in each post-intervention PDSA cycle and overall pre- to post-intervention. The mean dead volumes pre-intervention was 8.48mL and mean dead volumes in PDSA 1, 2, 3, and post total were 1.00, 1.21, 0.50, 0.93mL respectively with p< 0.01 for all cycles. Mean percentage loss pre-intervention was 7.38% and mean percentage loss in PDSA 1, PDSA 2, PDSA 3, and post total were 1.00, 1.21, 0.50, 0.93% respectively with p<0.01 for all cycles. These results are displayed in Appendix H Graph 1. The most commonly performed administration method pre-intervention was primary tubing (52%) with a mean dead volume and percentage loss with this method of 13.45ml and 11.86% respectively. The most commonly performed post intervention administration method was secondary tubing (93%) with a mean volume and percentage loss with this method of 0.79ml and 0.79% respectively which is a significant reduction between methods with p<0.01 (Appendix H Graph 2).

Interpretation/Discussion

Most providers in the pre-intervention phase used primary tubing sets to administer their antibiotics, but some used their 3M™ Ranger fluid warming tubing (Hotline) while others used syringes to pull out and flush their dead volumes (Appendix D Table 3). Very few providers were aware of how much volume they were leaving behind in the tubing sets, even those flushing their tubing sets. There was significant variety of methods used, and even the methods which resulted in near complete administration of antibiotic were ineffective because they resulted in administration outside the designated pre-incision time interval determined by the medical center—usually 15-60 minutes prior to incision (Bratzler et al., 2013). Overall, there was a significant reduction in dead volumes of antibiotic and percentage of medication lost by
changing practice to secondary tubing. While the overall reduction in lost volume and medication had statistical significance, the clinical significance is theoretical based on antibiotic dosing data. The reduction in medication loss from the most common method of primary tubing administration sets, though, is much more significant and may have a more significant clinical impact. There was widespread CRNA acceptance of the practice change with very little hesitancy to adopt the new practice. With strong provider adoption of the practice change and sustained reduction in medication waste, this intervention has shown to be a beneficial new practice for this medical center moving forward. One continuing threat was supply issues related to stocking of secondary tubing, but this proved not to be an issue with this project at this medical center.

Limitations included the observation of 200mL antibiotic bag administrations in the pre-intervention period due to low identified case counts which could alter the current data. Providers could have had differing beliefs about the importance of waste with larger bag volumes and may have employed different administration methods. In communicating with participants whose 200mL antibiotic administrations were witnessed, it did not appear that the larger volume of the bag affected their decision-making process related to administration method. However, even with volume percentages being smaller in 200mL antibiotic bags, the post-intervention volume percentage losses were significantly less than the pre-intervention phase, which points to the intervention being effective regardless of this limitation. The small number of observations in each post-intervention PDSA cycle (mean of 9.33 observations per cycle) also limited this project. Due to provider assignments, medication shortages, and time constraints, a smaller number of cases were available for observation than previously anticipated. A higher-powered study over a longer period of time may be helpful in validating the results of
this project, however the results are consistent with other observational studies and the strong statistical significance is a promising result for this intervention. Additionally, there was no randomization in this project and causation cannot be established.

**Cost-Benefit Analysis/Budget**

Project costs were minimal at an estimated $142.79 for supplies, technology, and paid staff time (Appendix I). CRNA staff time was not considered here as observations, communication, and education happened during paid time. Statistician time was provided by Goldfarb School of Nursing. Time meeting with the lead anesthesia tech to discuss stocking of anesthesia carts was covered during working hours. Salaries were calculated using the United States Bureau of Labor Statistics wage estimates (2020). Based on current supply acquisition costs, secondary tubing, which was the recommended practice change, bore a cost of $0.83/unit, and 20mL syringes cost $0.16/unit (Shepis; Frohn, 2021). Additional supplies included one clipboard, personally paid for, and printed data collection forms for each administration which were included in the student printing budget. Additionally, SPSS software and Microsoft Excel were used to record and analyze data with a combined cost of $134 (IBM; Microsoft, 2021). Although the largest cost of the project, SPSS had already been personally purchased, and Microsoft Excel services were provided through Goldfarb School of Nursing.

These costs, however, could be offset in the long run by using a less expensive product to safely administer small-volume antibiotics. Primary pump tubing costs the institution $3.71/unit and primary gravity tubing costs $3.20/unit compared to the $0.83/unit cost of secondary tubing (Shepis, 2021). If the current practice change is adopted by the institution after presentation of these results, cost savings could be between $4,311 and $5,239 within the first year resulting in costs being recuperated by the first month of implementation. (Wolfe January 2021; Shepis,
Because the project demonstrated significant improvements in small-volume antibiotic administration, further benefits could include a reduction in risk and potential for improved outcomes in morbidity, mortality, and hospital length of stay within the surgical patient population at the institution (Badia et al., 2017; Patient Safety Network, 2019). Improving these outcomes could decrease the significant hospital costs associated with these hospital-acquired conditions. Overall, the project presents the opportunity for tremendous cost savings and improvement in the quality of care for patients at this institution, thus achieving two of the Institute for Healthcare Improvement’s Triple Aim dimensions (2021b).

**Protection of Human Subjects/Ethical Considerations**

Patient identifiers were not collected or recorded in physical or electronic form during the course of this project. No patient identifiers were found on the medication or medication labeling. No patient identifiers were stored for later use. Only room numbers and case order were noted in order to assist with locating cases on the following day. The Washington University Department of Anesthesia and the Barnes Jewish Hospital Research Committee gave approval for this project with the specific endorsement of the Associate Director of Clinical Anesthesiology. CRNA participation in this quality improvement project was also approved as mandatory by the Director and Assistant Director of CRNA Activities for the Department of Anesthesiology alleviating the necessity for a formal consent process. Additionally, all participant demographic data was de-identified and stored on a secure database only accessible to project team members directly involved with data review and analysis.

**Conclusion**

The goals of this project were to promote the use of an evidence-based policy regarding the use of secondary tubing for small-volume antibiotics to reduce dead volume medication
waste and eliminate system and person holes in the administrative process of antibiotic prophylaxis for surgical patients. Clinical evidence supports the complete administration of prophylactic antibiotics to meet these goals, and the Infusion Nurses Society and Institute for Safe Medication Practices have laid out evidence for practice guidelines involving the use of secondary tubing and the pinch method to achieve complete volume administration. Results of this project show that this practice change is effective at reducing dead volumes and improving complete administration of antibiotics. A new departmental policy (Appendix C) will be proposed to foster consistent practice and to prevent potentially harmful errors from reaching the patient in the operating rooms at this large academic medical center. This institution was a strong candidate for implementation of this practice change as it promoted clinical inquiry and evidence-based practice. CRNAs working at this site benefited from the provided education by strengthening their clinical practices. The project intervention required minimal upfront cost and has tremendous upside both for cost-reduction and patient well-being.
References


Frohn, E. Personal communication, June 25, 2021.


https://doi.org/10.1136/bmj.320.7237.768


https://doi.org/10.1016/S1473-3099(14)70036-2


Shepis, E. Personal communication, March 1, 2021.


Wolfe, R. Personal communication on June 22, 2021.


Appendix A

Reason’s Swiss Cheese Model (Larouzee & Le Coze, 2020)
Appendix B

Table 1

Institute of Medicine Domains

<table>
<thead>
<tr>
<th>Domain</th>
<th>Project Application</th>
</tr>
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<tbody>
<tr>
<td><strong>Safe</strong></td>
<td>By completely and correctly administering antibiotics, patients received evidence-based care that is likely to prevent SSI and prevent growth of undesirable resistant bacteria.</td>
</tr>
<tr>
<td><strong>Effective</strong></td>
<td>Underdosing antibiotics provides a service that is not likely to be effective for the patient. Patients deserve to receive evidence-based care throughout the health system by every provider.</td>
</tr>
<tr>
<td><strong>Patient-Centered</strong></td>
<td>This intervention focused on the patients' well-being and health outcomes and respected them as individuals.</td>
</tr>
<tr>
<td><strong>Efficient</strong></td>
<td>This intervention reduced waste in the hospital by avoiding ineffective drug administration that delays proper treatment. By reducing waste, we can improve the timeliness of care and reduce future use of resources due to ineffective primary treatment.</td>
</tr>
<tr>
<td><strong>Timely</strong></td>
<td>This intervention improved the primary treatment modality for SSI prevention so that later doses of antibiotics are not needed. Future treatment may not be needed because of the improved timeliness of this intervention.</td>
</tr>
<tr>
<td><strong>Equitable</strong></td>
<td>The practice change was implemented for all providers and all patients so that every patient, regardless of personal characteristics, receives the same, effective care.</td>
</tr>
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</table>
Appendix C

TITLE: Secondary Infusion of Small-Volume Antibiotics for Surgical Prophylaxis

Policy Statements

1. A secondary infusion method, or IV piggy-back method, should be used for all surgical prophylactic antibiotics contained in bags of 100mL or less
2. All Anesthesia supply rooms and carts should be stocked with secondary tubing

Procedure

I. Assessment
   A. Assess appropriateness of prophylactic antibiotics for specific case according to clinical indication in conjunction with Surgical Antibiotic Prophylaxis Guidelines for Adult Patients under Clinical Protocols on the Anesthesia Intranet
   B. Identify perioperative antibiotic orders in the patient chart and discuss with surgical team in pre-op to confirm appropriate antibiotic prophylaxis.
   C. Ensure that patient has patent IV with primary fluid line in place
   D. Antibiotics should be initiated within the time window and redosed as specified in Surgical Antibiotic Prophylaxis Guidelines for Adult Patients

II. Plan
   A. Obtain antibiotic from pyxis or pharmacy
   B. Obtain secondary IV tubing from the anesthesia cart or anesthesia supply room
   C. Locate alcohol swabs

III. Administration
   A. Prime secondary tubing with medication
   B. Vigorously Scrub, with alcohol, the Y-site and all hubs and connections prior to accessing the line. Use the most proximal injection port of the primary line for access to the secondary infusion line. Key point: regardless of use of disinfection caps, if line is flushed with normal saline prior to connecting infusion and after removing disinfection cap, the Y-site and/all hubs and connections should be vigorously scrubbed with alcohol before connecting the infusion.
   C. Securely connect secondary tubing to proximal port on primary tubing
   D. Lower primary bag at least 9.5 inches using fully extended hanger hook.
   E. Ensure primary bag is completely below antibiotic bag
   F. Open roller clamp on secondary tubing
   G. Open vent on secondary drip chamber
   H. Use primary roller clamp to adjust gtt rate of medication to deliver dose over specified administration time.
      1. If Alaris pump is used, use “Secondary” administration feature to program rate
   I. Once all of the medication has been infused, close the secondary roller clamp, disconnect secondary tubing and discard. If medication remains in the secondary tubing after flow ceases, use the pinch method to complete administration.
IV. Pinch Method
   A. Once flow in the secondary tubing ceases, pinch the primary tubing closed above
   the secondary Y-site until the medication reaches 1.5 cm above the Y-site to
   prevent air from entering the primary set. (Usually takes around 2 minutes)
   B. Close the roller clamp on the secondary tubing to prevent backflow and
   disconnect the secondary tubing set from the primary line port.
   C. Discard administration set in appropriate receptacle.

V. Infusion Errors
   A. Failure to open the secondary clamp will prevent flow.
   B. Failure to open the secondary vent on the drip chamber may result in incomplete
   administration of certain IV bags
   C. Failure to properly lower the primary line below secondary fluid level will
   prevent flow.
   D. Connecting the secondary tubing to a more distal port on the primary line will
   result in incomplete administration of medication and backflow

VI. Documentation
   A. Document antibiotic start time and duration of infusion.
   B. Communicate time of initiation of antibiotic to surgical team during time out.

References

for delivering small-volume intermittent intravenous infusions. *Journal of Infusion
Nursing, 43*(1), 47-52. doi:10.1097/NAN.0000000000000355

Institute for Safe Medication Practices. (2020). Hidden medication loss when using a
primary administration set for small-volume intermittent infusions. *ISMP.*
https://www.ismp.org/resources/hidden-medication-loss-when-using-primary-
administration-set-small-volume-intermittent

Policies/Procedures

Thoele, K., Piddaubny, M., & Ednalino, R. (2018). Optimizing drug delivery for small-
volume infusions. *Journal of Infusion Nursing, 41*(2), 113-117.
DOI:10.1097/NAN.0000000000000268
Appendix D

Table 2

Participant Demographics

<table>
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<tr>
<th></th>
<th>Pre-intervention observations (N=21)</th>
<th>Post-intervention observations (N=28)</th>
<th>p</th>
<th>Pre-intervention providers (N=7)</th>
<th>Post-intervention providers (N=9)</th>
<th>p</th>
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<tr>
<td>Age</td>
<td>39.48</td>
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<td>YOE</td>
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<td>12.22</td>
<td>0.41</td>
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Table 3

Rate of Tubing Method Choice (Percentage of Total)

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<tr>
<th></th>
<th>Primary</th>
<th>Primary with flush/syringe pull-back</th>
<th>Hot line</th>
<th>Secondary</th>
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<tr>
<td>Pre (N=21)</td>
<td>11 (52%)</td>
<td>8 (38%)</td>
<td>2 (9%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Post (N=28)</td>
<td>0 (0%)</td>
<td>2 (7%)</td>
<td>0 (0%)</td>
<td>26 (93%)</td>
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Table 4

Observation Demographics

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<tr>
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<th>Pre-Intervention</th>
<th>Post-Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antibiotic</td>
<td>Unasyn (7), Flagyl (5), Vancomycin (4), Cipro (2), Clindamycin (2), Meropenem (1)</td>
<td>Flagyl (23), Unasyn (3), Zosyn (1), Cipro (1),</td>
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<tr>
<td>Case Type</td>
<td>GU (14), GYN (7)</td>
<td>GYN (22), GU (4), GI (2)</td>
</tr>
<tr>
<td>Volume</td>
<td>100 (13), 200 (7), 50 (1)</td>
<td>100 (27), 50 (1)</td>
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## Antibiotic Questionnaire

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<th>2</th>
<th>3</th>
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<td>Surgical Case</td>
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<td>GI</td>
<td>GYN</td>
</tr>
<tr>
<td>Dosage</td>
<td>MG</td>
<td>MG</td>
<td>MG</td>
</tr>
<tr>
<td>Concentration</td>
<td>MG/ML</td>
<td>MG/ML</td>
<td>MG/ML</td>
</tr>
<tr>
<td>Volume</td>
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<td>ML</td>
<td>ML</td>
</tr>
<tr>
<td>Labeling Accurate</td>
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<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Type</td>
<td>Syringe</td>
<td>Bag</td>
<td>Syringe</td>
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<tr>
<td>Reconstituted</td>
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<td>N</td>
<td>Y</td>
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<tr>
<td>Type of access</td>
<td>PIV Central Other</td>
<td>PIV Central Other</td>
<td>PIV Central Other</td>
</tr>
<tr>
<td>Tubing Set Used</td>
<td>PG PP S BT IVP</td>
<td>PG PP S BT IVP</td>
<td>PG PP S BT IVP</td>
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<tr>
<td>Location Initiated</td>
<td>Preop OR</td>
<td>Preop OR</td>
<td>Preop OR</td>
</tr>
<tr>
<td>Time Before Incision</td>
<td>&lt;15</td>
<td>15-60</td>
<td>&gt;60</td>
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<tr>
<td>Duration of Administration</td>
<td>min</td>
<td>min</td>
<td>min</td>
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<tr>
<td>Order Placed By Surgeon Prior to Surgery</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
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</table>
Appendix F

Educational Flyer

Small-Volume Antibiotic Practice Change

Secondary (IVPB) Tubing for ALL 50mL and 100mL Antibiotic Bags

Recommended by the ISMP and Infusion Nurses Society
Less priming volume = less risk of unintended waste

WHY??

- Medication loss from primary infusion sets can be significant for small-volume bags.
- Losses in primary tubing have been shown to range from 14-47% of intended dosage.
- Evidence that up to 50% of small-volume antibiotics are not being completely infused.
- Underdosing could result in ineffective prophylaxis or antimicrobial resistance

Observation of Parkview Tower Small-Volume Antibiotic Losses

TUBING METHOD

- Gravity
- Gravity with flush/temperature
- Pump
- Pump with flush/temperature
- Hot line

VOLUME OF MEDICATION

BLUE: AVERAGE DEAD VOLUME  RED: AVERAGE % LOSS

Errors to Avoid

⇒ Attach secondary tubing to the proximal port on the patient’s IVF line
⇒ Hang IVF bag on hook completely below antibiotic bag
⇒ Use pinch method to administer any remaining medication in tubing

<table>
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<td>Approval</td>
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<td>Recruitment and Baseline Data Collection</td>
<td>September-October, 2021</td>
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<tr>
<td>Educational Meetings</td>
<td>November, 2021</td>
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<tr>
<td>Post-education Data Collection #1</td>
<td>November, 2021</td>
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<tr>
<td>PE Data Collection #2</td>
<td>November-December, 2021</td>
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<tr>
<td>PE Data Collection #3</td>
<td>December, 2021</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>December, 2021-January, 2022</td>
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<tr>
<td>Presentation of Results</td>
<td>January-February, 2022</td>
</tr>
</tbody>
</table>
Appendix H

Graph 1
Dead Volumes and Percentage Loss Over Time

Graph 2
Mode Tubing Method Pre vs Post-Intervention
Appendix I

Table 5

*Budget Table*

<table>
<thead>
<tr>
<th>Nature of Expenditure/Item</th>
<th>Cost per Unit</th>
<th># Units</th>
<th>Total Estimated Cost</th>
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<tbody>
<tr>
<td><strong>Personnel</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CRNA 10 min. education</td>
<td>90.96</td>
<td>10min X 30</td>
<td>0-during breaks and designated continuing education time</td>
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<td>Statistician</td>
<td>46.72</td>
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<td>0-provided by Goldfarb</td>
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<td>Lead anesthesia technician</td>
<td>15.41</td>
<td>0.5</td>
<td>7.71</td>
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<td><strong>Materials and Supplies</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Secondary Admin. Set</td>
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<td>28</td>
<td>23.24</td>
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<tr>
<td>20mL syringes</td>
<td>0.16</td>
<td>49</td>
<td>7.84</td>
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<td>Printing</td>
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<td>Clipboard</td>
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<td>5</td>
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<tr>
<td>Paper Ream</td>
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<td>1</td>
<td>0-student printing budget</td>
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<tr>
<td><strong>Technology Hardware/Software</strong></td>
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<td>SPSS</td>
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<td>99</td>
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<tr>
<td>Microsoft Excel</td>
<td>6.99/mo</td>
<td>5</td>
<td>0-provided by Goldfarb</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td>142.79</td>
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