RESEARCH ARTICLE

Better Pairing Propofol Volume With Procedural Needs: A Propofol Waste Reduction Quality Improvement Project

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ABSTRACT

BACKGROUND AND OBJECTIVES: Propofol facilitates deep sedation without requiring intubation and is often used by infusion to maintain sedation. Variability in ordering and preparation strategies resulted in significant propofol volumes wasted at the conclusion of procedures in our clinic. With drug shortages now common, we designed a quality improvement initiative to reduce our propofol waste.

METHODS: Data collection during the preintervention phase reflected current practice trends. Two propofol dosing tables (≥50 or <50 kg) were designed to estimate the volume of propofol infusion required for sedations spanning 15 to 180 minutes. Nurses prepared propofol infusions as directed by these tables. The primary outcome measure was reduction in waste when the infusion was prepared by standardized strategy versus usual practice. Balancing measures included occurrences of insufficient infusion volume and premature awakenings from deep sedation. Waste volumes were plotted and displayed chronologically in statistical process control charts for the clinic and individual providers.

RESULTS: A total of 155 patients received a propofol infusion to maintain deep sedation. The preintervention phase included 77 patients, and the intervention phase included 78 patients. Special cause variation was achieved in the intervention phase. Median (interquartile range) propofol waste volume per procedure declined from 45.6 mL (24.3–71 mL) to 14.3 mL (9.6–19.4 mL), representing a 68% waste reduction.

CONCLUSIONS: Using an internally derived systematic approach to ordering and preparing a propofol infusion, we reduced variability, reduced propofol waste, and created cost savings for our organization. This approach is tailorable to other infusions and clinical settings.

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The number of sedated procedures performed on pediatric patients outside the operating room continues to increase. Children often cannot understand the need for medical interventions and may respond with apprehension or even develop a preconditioned fear response to subsequent medical interventions.[1] In this context, pediatric sedation is used to reduce anxiety, pain, or excessive movement. Pediatric sedation clinics (PSCs) typically operate with anesthesia oversight and routinely support outpatient elective procedures on American Society of Anesthesiologists physical status classification I and II patients.[2]

Propofol is a preferred medication to facilitate deep procedural sedation without requiring definitive airway placement.[3] Propofol is titratable, lipid soluble, and promptly redistributes into peripheral tissues, which accounts for both rapid onset of and emergence from sedation. Factors unique to each sedation experience, such as patient weight, proceduralist, and length of procedure, impact the amount of medication ultimately required to maintain an acceptable level of sedation for an individual patient.

Now common in the US health care system supply chain, drug shortages have downstream effects on patient care. Sedatives are not immune to this situation, and propofol was most recently on shortage in 2010.[4] Drugs used in substitution for those on shortage may have different adverse effect profiles and local pharmacy preparation requirements.[5] For a busy sedation clinic, drugs used in substitution for propofol may result in a protracted recovery process that delays discharge and patient turnover. Financially, drug waste is also a habitual expense that invites administrative regulation and rationing during recurrence of drug supply crisis.

Case review in our clinic revealed that large volumes of propofol were frequently wasted at procedural conclusion. We hypothesized that a standardized propofol ordering and preparation strategy tailored to a patient's procedural needs could reduce our drug waste footprint. To this end, we devised the following aim statement for this quality improvement (QI) initiative: Using a time series design with equal assessment periods before and after an intervention, we aim to reduce the average waste volume of our propofol maintenance infusion across all sedated procedures by 50% of preintervention levels.

METHODS

This project was conducted in the PSC of a 220-bed, tertiary care medical center. The PSC is housed within the PICU inpatient environment. The PSC performs ~350 to 400 sedated procedures each year on children of varying ages (50 weeks postconceptual age–23 years of age) and developmental stages. Although it is predominantly an outpatient service, the PSC also supports sedated procedures for inpatients. PSC personnel includes 3 board-certified pediatric intensivists, 2 registered nurses with pediatric-specific procedural sedation experience, and 1 pediatric sedation scheduler. Most (85%) of the patients served by the PSC require deep sedation and receive propofol. Propofol is prepared at bedside by PSC nurses. Intensivists induce sedation through hand-administered propofol bolus doses but largely maintain sedation with a propofol infusion run throughout the duration of the procedure.

The hospital's preferred process improvement model of find a process, organize a team, clarify the current process, understand cause of variation, select the process to improve, plan, do, check, and act guided the study team.[6] Study team members included both of the PSC registered nurses, the unit pharmacist, and the pediatric intensivist serving as chief of the sedation service. The hospital's quality services division concurred with the designation of this project as QI, and the hospital's human research protections office determined further human subjects review was unnecessary.

The medication plan for each sedation is dependent on patient comorbidities, allergies, and characteristics of the planned procedure. For example, patients scheduled for sedated EEGs often receive a dexmedetomidine infusion to not mask seizures. Patients undergoing noxious procedures may require both sedation and analgesia, most commonly provided with a sedative infusion and bolus doses of intravenous narcotics. We identified our study population as any PSC patient who received a propofol infusion as a single agent for maintenance of deep sedation. Patients sedated with an infusion other than propofol (such as dexmedetomidine) or sedated with another intravenous medication in addition to propofol (such as a narcotic) were excluded. Patients receiving preprocedural administration of an oral anxiolytic or inhalational nitrous oxide before propofol were not excluded.

Preintervention Phase

To better clarify current propofol practices in our clinic, study team members first sought to understand what variables influenced provider decisions when ordering infusion volume. The electronic health record (EHR) contained only 2 default options, 20 or 50 mL, for propofol infusion volume. There was no EHR functionality for a free-text volume. To discern any systematic differences in ordering practices, the 3 pediatric intensivists were independently questioned by the PSC nurses regarding what influenced their ordering preferences for these 2 volumes. Two providers commented that the weight of the child, their perceived length of the procedure, and whether sedation began in the PSC and then traveled off-site (to radiology) all influenced the choice of which propofol volume they ordered. The third intensivist commonly ordered the larger propofol volume for all procedures to ensure ample supply. Although all 3 providers endorsed awareness of propofol waste in the clinic, they all also made mention that current EHR functionality precluded ordering tailored volume options.

Next, we needed to clarify our propofol supply and preparation processes. Pharmacy stocks propofol (standard concentration of 10 mg/mL) in 20- and 100-mL vials within the PICU medication dispensing system for centralized access by both PICU and PSC staff. Aspirating these vials at the bedside, PSC nurses prepare at least 1 bolus syringe and a maintenance infusion syringe for each patient. Bolus

syringes are prepared as full 10-mL syringes by clinic convention regardless of patient characteristics or planned procedure. Typical induction bolus doses in our clinic are 2 to 3 mg/kg per dose to an adult maximum of 100 mg per dose, which would use an entire 10-mL bolus syringe. Therefore, if a provider orders a 20-mL maintenance infusion, a minimum of two 20-mL vials are required to prepare the infusion syringe (the entirety of 1 vial) as well as a bolus syringe (2 from the second vial, in this case). If a provider orders a 50-mL infusion volume, either a single 100-mL vial or three 20-mL vials could be used to prepare the infusion and bolus syringes. If using the 100-mL vial, 50 mL would be drawn into the infusion syringe and five 10-mL bolus syringes would be prepared. If using three 20-mL vials, 50 mL would be drawn into the infusion syringe and only one 10-mL bolus syringe would be prepared. Should procedure length exceed the initial maintenance infusion volume prepared, an extra bolus dose syringe (if available) is placed on the pump before a new propofol vial is obtained for this purpose. Per pharmacy and package insert guidance, unused bolus dose syringes are wasted at procedural conclusion and not used for subsequent patients.[7]

We then conducted a retrospective chart review of all cases performed by our clinic from April 2015 through March 2016 to identify our most common sedated procedures. Of the 351 cases reviewed, gastrointestinal scopes (38%), noninvasive radiology (29%), lumbar punctures (LPs) (13%), and auditory brainstem response (ABR) testing (5%) were most frequently supported. Given this historical data, we stratified sedated procedures into 5 categories for this project: esophagogastroduodenoscopy, MRI, LP, ABR testing, and all others.

Using this stratification scheme, we prospectively collected data for 3 months to reflect current practice trends regarding active sedation length and the volume of propofol that went unused at the end of each procedure. For the purposes of this project, active sedation length indicated the time from initiation of the propofol infusion to its discontinuation. All of our providers practiced similarly in that they started the propofol infusion immediately after bolus dose propofol induction and stopped the infusion at the time of the procedure's end. Data were collected chronologically during this phase in order of patient presentation to the PSC and included the categorical procedure type, active sedation length (minutes), patient weight (kilograms), sedating provider, volume (milliliters) of propofol infusion ordered by provider, and volume (milliliters) of propofol bolus and infusion wasted at the end of the procedure.

Intervention Phase

The starting propofol infusion dose in our clinic depends on the patient's weight being $\geq$50 kg (starting dose of 150 μg/kg per minute) or $<$50 kg (starting dose of 250 μg/kg per minute). During the previous phase, we discovered that providers' preferences when ordering an infusion, as well as nurses' vial selections (multiple 20-mL vials versus a single 100-mL vial) when preparing an infusion posed variation contributing to propofol waste. To standardize the minimum volume of propofol infusion necessary for a given procedure, we created 2 propofol volume requirement tables spanning procedural length in 15-minute intervals from 15 to 180 minutes (Fig 1). We also standardized nurses' vial selections for infusion preparation. For infusion volumes $>$60 mL, PSC nurses used a single 100-mL propofol vial to prepare the infusion and bolus syringe(s). For infusion volumes $\leq$60 mL, PSC nurses used the smallest number of 20-mL vials to prepare both the infusion syringe and at least 1 bolus syringe.

For each sedation during this phase, PSC nurses used patient body weight and median active sedation length of the pending procedure to prepare the propofol infusion as suggested by the appropriate propofol volume requirement table. Each PSC nurse served as the other nurse's quality control to ensure correct preparation. Although all 3 intensivists were aware that volume requirement tables were created for this project, the tables were not posted for provider use, because the EHR still lacked the ability to order a tailored infusion volume. Data were collected chronologically during this phase in order of patient presentation to the PSC. At the end of each case, the categorical procedure type, patient weight (kilograms), sedating provider, volume (milliliters) of propofol infusion ordered by provider, and volume (milliliters) of propofol bolus and infusion wasted at the end of the procedure were collected. Similar to the preintervention phase, this phase lasted 3 months.

Study of the Intervention

Our primary outcome measure was the median percent reduction in propofol waste when the infusion was prepared in accordance with a standardized propofol ordering and preparation strategy as compared with preparation by usual practices. Of note, if a previously prepared bolus syringe was used to augment infusion volume for a procedure lasting longer than anticipated, any remaining propofol in that syringe at procedural conclusion was counted against infusion waste and not bolus waste. The number of times this situation arose was used as a balancing measure. Also, with anticipated use of smaller infusion volumes during the intervention phase, the occurrence of premature awakenings from deep sedation was used as a balancing measure.

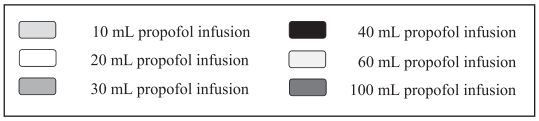
Data Analysis

Active sedation length was only assessed during the preintervention phase. Active sedation length and propofol waste volumes were calculated as median and interquartile ranges, given the nonnormality of data in the procedural subgroups. Total propofol waste volumes (infusion and bolus volume in milliliters) for each procedure during the preintervention and intervention phases were plotted and displayed chronologically in statistical process control individual (X) and moving range (MR) charts for all providers in aggregate as well as for each provider individually. Established rules were used to identify special cause variation.[8] All analyses were performed by using Excel for Microsoft Office 2013 (Microsoft, Redmond, WA).

RESULTS

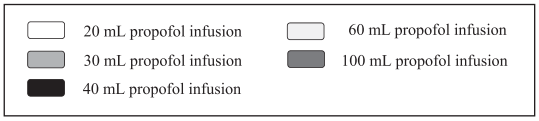
During the time periods studied, 183 patients underwent sedation in the PSC.

A



Active Sedation Length (in Minutes)	Patient Weight (in Kilograms)								
180	22.5	45	67.5	90	112.5	135	157.5	180	202.5
165	20.6	41.3	61.9	82.5	103.1	123.8	144.4	165	185.6
150	18.8	37.5	56.3	75	93.8	112.5	131.3	150	168.8
135	16.9	33.8	50.7	67.5	84.4	101.3	118.1	135	151.9
120	15	30	45	60	75	90	105	120	135
105	13.1	26.3	39.4	52.5	64.6	78.8	91.9	105	118.1
90	11.3	22.5	33.8	45	56.3	67.5	78.8	90	101.3
75	9.4	18.8	28.1	37.5	46.9	56.3	65.6	75	84.4
60	7.5	15	22.5	30	37.5	45	52.5	60	67.5
45	5.6	11.3	16.9	22.5	28.1	33.8	39.4	45	50.6
30	3.8	7.5	11.3	15	18.75	22.5	26.8	30	33.8
15	1.9	3.8	5.6	7.5	9.4	11.3	13.1	15	16.9
	5	10	15	20	25	30	35	40	45

B



Active Sedation Length (in Minutes)	Patient Weight (in Kilograms)						
180	135	148.5	162	175.5	189	202.5	216
165	123.8	136.1	148.5	160.9	173.3	185.6	198
150	112.5	123.8	135	146.3	157.5	168.8	180
135	101.3	111.4	121.5	131.6	141.8	151.9	162
120	90	99	108	117	124	135	144
105	78.8	86.6	94.5	102.4	109.3	118.1	126
90	67.5	74.3	81	87.8	94.5	101.3	108
75	56.3	61.9	67.5	73.1	78.8	84.4	90
60	45	49.5	54	58.5	63	67.5	72
45	33.8	37.1	40.5	43.9	47.3	50.6	54
30	22.5	24.8	27	29.3	31.5	33.8	36
15	11.3	12.4	13.5	14.6	15.8	16.9	18
	50	55	60	65	70	75	80

FIGURE 1 A, Propofol volume in milliliters requirement for patients <50 kg (250 μg/kg per minute dosing strategy). B, Propofol volume in milliliters requirement for patients ≥50 kg (150 μg/kg per minute dosing strategy).

However, 10 patients in the preintervention phase and 18 patients in the intervention phase were excluded from analysis, because they did not receive a propofol infusion. No patient was excluded from analysis because of the requirement for a second intravenous medication, in addition to propofol, to meet sedation goals. The final analysis included 155 patients with 77 patients in the preintervention phase (June 1, 2016–August 31, 2016) and 78 patients in the intervention phase (February 1, 2017–April 27, 2017).

Balancing Measures

No patient in either phase of this project experienced premature awakening before procedural conclusion. During the preintervention phase, there was 1 occurrence in which a previously prepared 10-mL bolus syringe was used to augment infusion volume for a protracted imaging procedure. The intervention phase had 2 separate occurrences in which a previously prepared 10-mL bolus syringe augmented infusion volume, and both of these instances occurred in the setting of multiple procedures combined under a single sedation experience.

Phase Comparison Data

Although the total number of procedures was equitable between phases, there were twice as many esophagogastroduodenoscopies and ABRs in the preintervention phase and twice as many MRIs in the intervention phase (Table 1). During the preintervention phase, the median with interquartile range of propofol volume wasted in aggregate analysis of all cases was 45.6 mL (24.3–71 mL). Similar analysis during the intervention phase was 14.3 mL (9.6–19.4 mL), which represented a median 68% waste reduction per procedure from preintervention levels. These results are visually displayed in the composite propofol waste volume statistical process control X-MR chart for all providers (Fig 2). Standardization of our propofol processes in the intervention phase was a deliberate attempt to introduce special cause variation, which was ultimately achieved. Given a clear change in our processes, new control limits were calculated for the data in the intervention phase. However, we also noticed special cause variation in the preintervention phase, because the last 13 procedures in this phase had waste volumes that trended below the preintervention centerline.

Provider Comparison Data

Total propofol waste volumes (infusion and bolus volume in milliliters) were also plotted chronologically in separate statistical process control X-MR charts for each provider (Fig 3; MR charts not shown). Preintervention data points for each provider remained within control limits. However, special cause variation was seen with provider 2 who had 10 consecutive data points below the centerline near the end of the preintervention phase. Provider 1 demonstrated a similar trend but to a lesser extent with only 6 consecutive data points below the preintervention centerline.

Given the special cause variation seen with the last 13 preintervention procedures in the composite X-MR chart, we reviewed each provider's raw data. We saw that

TABLE 1 PreIntervention and Intervention Metrics Stratified by Procedure Type

	Sedation Length, min, Median (IQR)	Preintervention		Intervention	
		No. Procedures	Total Waste, mL, Median (IQR)	No. Procedures	Total Waste, mL, Median (IQR)
All procedures	—	77	45.6 (24.3–71)	78	14.3 (9.6–19.4)
EGD	15.5 (13–17.8)	28	30 (18.7–68.2)	14	13 (10–18)
MRI	70.5 (53.3–75.5)	12	63 (51–72.5)	24	16 (10–21.8)
LP	24 (7–14)	15	30 (24.5–83.2)	8	7 (4.7–16.2)
ABR	78 (61–109.3)	6	75 (55.5–80.8)	3	20 (17–23.3)
Other[a]	68.5 (36.5–89.5)	16	40 (21.7–62.2)	29	14 (7–21.2)

Total waste refers to infusion and bolus volume. EGD, esophagogastroduodenoscopy; —, not applicable.
[a] Includes any sedated procedure other than the 4 named categories, as well as combinations of procedures (even if categorical) performed during a single sedation experience.

providers 1 and 2 performed all 13 of these procedures. Additionally, these procedure types composed an unusual string of short sedations, as 11 of the 13 were esophagogastroduodenoscopies or LPs. However, provider 2's ordering practices did appear to change throughout the preintervention phase. Provider 2's preference for ordering a 20-mL infusion volume increased from 4 (of 19) times during the first half of attributable procedures in this phase to 11 (of 18) times for those during the last half of this phase.

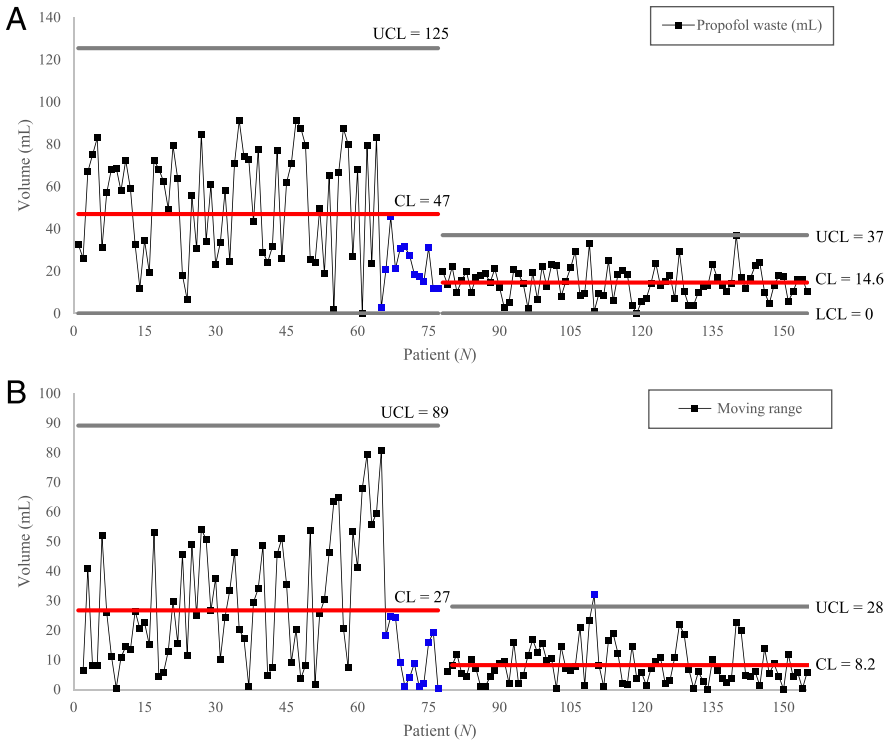


FIGURE 2 Composite X-MR chart for total propofol waste (infusion and bolus volume in milliliters) per procedure for each provider. A, Propofol waste. B, Moving range. The break on the x-axis with recalculation of control limits separates preintervention from intervention data points. Blue markers indicate special cause variation (in the preintervention phase) and a single out-of-control data point in the intervention phase (MR chart; bolus syringe was used to augment infusion during a longer than anticipated procedure). CL, control limit; LCL, lower control limit (set at 0); UCL, upper control limit.

DISCUSSION

Now common, drug shortages have the potential to negatively impact patient care. Medications substituted for drugs on shortage may be less familiar to providers or possess different dose ranges and adverse effect profiles, all of which may increase risk of medication error.[5] When specifically considering sedative and anesthetic agents, substitutions for shortage medications may lead to delayed onset of sedation, increased recovery times, and need for medications used in combination to achieve desired effects. Preparation of medications substituted for those on shortage may also have a cost differential or require different preparation methods by pharmacy.[5]

By better pairing propofol volume with anticipated procedural needs, we found the QI initiative yielded a median 68% waste reduction, or 31.3 mL per procedure, from preintervention levels. Practically, this volume equates to three 20-mL propofol vials saved every 2 procedures. The average wholesale price of propofol ranges from $0.10 to $0.14/mL for generic and brand name formulations, respectively.[6] With a current workload of 400 sedations annually and most of those propofol sedations, the PSC stands to conserve 12 520 mL of propofol and ~$1200 to $1700 each year. Reducing our propofol waste footprint supports our organizational mission of resource stewardship at the lowest level.

Through the model of find a process, organize a team, clarify the current process, understand cause of variation, select the

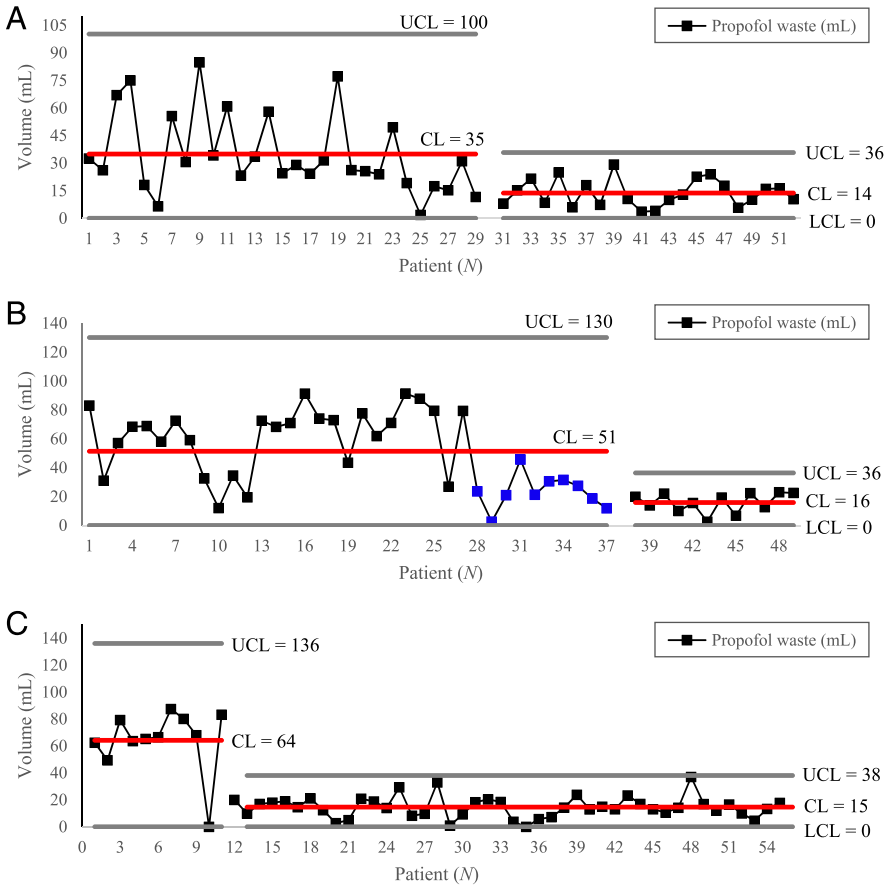


FIGURE 3 X-MR charts for total propofol waste (infusion and bolus volume in milliliters) per procedure for each provider. A, Provider 1. B, Provider 2. C, Provider 3. Respective moving range charts are not shown. The break on the x-axis with recalculation of control limits separates preintervention from intervention data points. CL, control limit; LCL, lower control limit (set at 0); UCL, upper control limit.

process to improve, plan, do, check, and act, we explored human and systems variables that contributed to propofol waste in our clinic. Although 2 of our 3 intensivists reported considering factors unique to each sedation experience when ordering propofol infusion volume, subjective impressions of drug need were often inaccurate. By creating propofol volume requirement tables tailored to body weight and active sedation length, we attempted to provide an objective measure to guide preparation of propofol infusion volume for our population. However, by also standardizing vial selection for infusion volume >60 or ≤60 mL, we eliminated variability and waste contribution from individual nurses' propofol vial selections. This realization of a difference in vial selection (multiple 20-mL vials versus a single 100-mL vial) among our 2 sedation nurses was discovered near the end of the preintervention phase. We hypothesize that the special cause variation observed during the latter 13 short procedures in this phase was attributed in part to this realization. Although the propofol infusion volume was prepared per physician orders during preintervention, bolus volume waste could be significantly larger for short procedures if using 100- vs 20-mL vials. With such a small clinic, discussions of this project certainly occurred among staff, heightening awareness of personal contributions to drug waste. This may also explain the preintervention special cause variation seen for provider 2, specifically.

With regard to systems variables, the EHR initially contained only 2 discrete volume options for ordering a propofol infusion (20 and 50 mL). As such, further infusion volume options (10, 30, 40, and 100 mL) were added to the EHR after completion of this project. Although EHR options target ordering providers, the consistency of PSC nursing staff cannot be underestimated in sustaining drug waste reduction. Intensivists rotate clinical duties on a regular basis, but dedicated PSC nursing staff participate in every sedation and will continue to drive process improvement. For example, as new proceduralists join our department (or at least annually given military provider movement cycles), we will continue to revalidate the active sedation length for our commonly supported procedures to ensure this approach to propofol preparation remains optimal for our clinic.

Several limitations of this project deserve mention. In our attempt to capture consistent propofol infusion dosing behavior by our providers, we did not discretely evaluate the impact of infusion dose titration (from starting dose) on infusion volume when building our propofol volume requirement tables. Although each phase lasted 3 months, project phases were not contiguous because of an alternating schedule of military training obligations for 2 of the 3 intensivists. Even with this offset, provider 3 was unavailable for most of the preintervention phase, whereas provider 2 was unavailable for most of the intervention phase. Smaller provider subgroups in these phases can affect the validity of their waste volume centerline and control limit calculations. However, when viewed collectively, charts for all 3 providers reveal a similar waste reduction trend in the intervention phase with reduced centerlines and tighter control limits.

Although our waste reduction results may not be easily generalizable because of factors unique to our hospital system, our project methods can be replicated and customized to apply to other clinical settings. Active sedation length stratified by procedure type can be calculated for a known population served by a consistent

group of proceduralists and sedation providers. Although propofol is a mainstay for titratable sedation support, it may not be the preferred medication for all settings and situations. Even so, our drug volume requirement tables could be replicated for other continuous agents used inside or outside the operating room, to include dexmedetomidine and narcotic infusions.

CONCLUSIONS

Through an internally derived systematic approach to ordering and preparing a propofol infusion, we reduced variability in propofol ordering and infusion volume preparation practices. With this project, we reduced propofol waste in our clinic and created cost savings for the organization. Although these results may not be easily generalizable given the variety of sedation venues, each with their own unique human- and systems-related factors, our processes are certainly tailorable to other infusions and clinical settings.

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