Evaluation of Operational Efficiencies in Pediatric Pharmacy Batch Production

by

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BACKGROUND

It is well published that more frequent batch production leads to less waste. Toerper et al.[i] published a simulation analysis conducted in a 205-bed children's center within an academic tertiary care hospital where batch production went from one cart fill a day to a three batch a day system in the effort to reduce waste. They evaluated 58 batch scenarios which simulated one to six batches per day. They concluded that optimal batch preparation times depend on medication administration and discontinuation times. Batches should be avoided being prepared during times when discontinuations frequently occur and should be positioned as close as possible to the medication administration time. The largest incremental savings was found in increasing batch frequency from one to two batches a day. With each increased batch the incremental savings decreased. When costs of delivery and production were incorporated into the simulation, producing more than three batches per day became less cost effective because the cost of delivery and production outweighed that of drug cost savings. By implementing a three batch a day system they achieved a 31.3% reduction in waste, from 28.7% to 19.7% of batched medications. This was a saving of $183,380 in drug cost and a net annual savings of $97,970 when increased cost of labor for delivery ($85,410) was taken into account.

Jenkins et al.[ii] described moving from an every 12 hour batch frequency to every 4 hours at a large academic medical center which services primarily adults. Their intervention focused on ensuring doses were being prepared close to the time of administration however did not take into account cost of increased delivery time. They found a 31% reduction in batched doses credited daily from 26% to 18%, a cost savings of over $120,000 annualized, and the opportunity to relocate half a pharmacy technician full-time equivalent.

Tilson et al.[iii] created a mathematical model for medications prepared and delivered to evaluate several different potential interventions including rescheduling print times, increasing number of batches, and reordering production within a batch. Using this model the team considered changing batch production from one batch a day to two. They predicted that while this would reduce waste by 28%, it would also increase employee hours by one-and-a-half hours every day in increased delivery time. Once the two batch production schedule was implemented, they found a 33% reduction in waste; however, they did not report on actual increased delivery time or expense from this.

Hintzen et al.[iv] used lean process management to decrease pharmaceutical waste of compounded sterile products by increasing the number of intravenous (IV) batches. They moved from batching IV medications twice a day, every 12 hours, to five times a day at 4am, 8am, 12pm, 4pm, and 7pm. As a result they decreased their IV waste by 40%, saving a net of $238,256 annually.

The optimal batch production and delivery schedule for a pediatric institution is unknown. Anecdotal reports from a Children's Hospital Association Directors of Pharmacy Survey reports batch schedules of two to twenty batches per day. With this reported wide range, pediatric institutions are left to make individualized decisions and often create complex medication delivery systems. Additionally, there are few pediatric institutions comparable in size and complexity to benchmark against. Two specific larger free-standing pediatric institutions which have recently evaluated their batch production times reported three batches per day and five batches per day.

Texas Children's Hospital (TCH) is the nation's largest freestanding children's hospital[v] with 750 licensed inpatient beds housed in three different buildings. With the recent addition of Legacy Tower, home to 130 ICU beds and two satellite pharmacies, as well as the increasing number of medication backorders, the pharmacy department has been forced to become increasingly efficient in providing safe and timely medications for our pediatric patient population. In contrast to adult hospitals, where commonly accepted best practice is to have 90% of doses come from automated dispensing cabinets, at TCH each medication dose is drawn up patient specific and delivered to the patient's bedside medication drawer. Pediatric weight-based dosing, without any significant dose rounding protocols, leads to each medication being specially tailored for the particular patient without the ability to reuse returned medications for another patient.

In 2011 batches were printed and delivered six times daily with dosage-form specific updates in between batch prints at a variety of times, leading to a very complex system. The current batch production schedule includes ten batch prints every two hours and six medication deliveries every four hours from 6am-12am each day. Scheduled doses are printed in a batch six to twelve hours before the scheduled administration time with the most frequent administration times of 9am and 9pm daily. TCH implemented this batch production schedule with the goal of reducing drug waste by reducing the amount of time between a label printing and nursing administering the medication; however at that time, the counter measures of delivery and production time were not taken into account. Technicians must obtain medications to draw up patient specific doses twice, for two different batch prints, before the doses are delivered. Each delivery takes a significant amount of time as technicians must walk from central pharmacy to each patient's bedside medication drawer across all hospital buildings. The purpose of this project was to evaluate operational efficiencies at six points in time, taking into account different batch production and delivery schedules.

METHODS

This is a retrospective, single-arm study that compared operational efficiencies and waste at six points in time with different batch production and delivery schedules. Due to the retrospective nature of this study there was no use of control subjects. The primary outcome of this study was to evaluate which batch production schedule was most efficient taking into account drug waste and technician time in production and delivery. Secondary outcomes included each individual aspect that goes into the primary outcome including: doses wasted, drug dollars wasted, production time, and delivery time.

A literature search was performed to establish industry standards of acceptable percent of wasted batch doses. Benchmarking with comparing institutions will be conducted to survey other institutions' batch production and delivery schedules.

All doses produced via the central pharmacy batch printed in January 2011, August 2011, January 2014, August 2014, January 2018, and August 2018 were identified from the electronic medical record. The years of 2011, 2014, and 2018 were strategically chosen to be evaluated because they span several significant operational changes, batch production, and delivery schedules at the institution. The current electronic medical record was implemented in fall of 2010, therefore 2011 was the oldest data that could be obtained. Evaluating the months of January and August was chosen to account for the seasonal fluctuation in census.

Doses that were printed yet not administered were identified as waste. The percent waste and total cost of waste were calculated. The cost of the medication was obtained from the electronic medical record, which calculates order cost based on the average wholesale price at the time of order as reported by the clinical drug information provider.

Production and delivery time were calculated based on the batch production and technician workflow schedule at each of the time points included. Production time was calculated by reviewing each order produced in the batch for the month. Each order was allocated a standard production time based on the preparation complexity. See table 1 for the time allocation. These time allocations were historically used for quarterly workload estimates and employee productivity evaluations at the institution. Additionally, 0.40 minutes were added for each drug used in each batch to account for the time it takes to pull each drug off the shelf.

Table 1. Production time estimate

Preparation type	Minutes
Bulk	0.5
Unit dose	0.75
Unit dose, crushed tab	2
Unit dose, chemotherapy	1
Injectable, IV simple syringe	1
IV admixture	3
Oral liquid	0.75
Oral Solid	0.75
Oral solid, narcotic or non-formulary	2

Delivery time was estimated by conducting a real-time delivery time study. Delivery time was recorded over 4 days for 3 batch time deliveries. This time was applied to the actual number of bedsides delivered to during the time study and averaged. The average time per bedside was calculated as 2.15 minutes per bedside. For each month, the number of bedsides, based on daily batch medication orders, for each delivery was calculated and multiplied by 2.15 minutes to get the delivery time. Using current technician average salary of $15 per hour, cost of production and delivery time were calculated.

After the above data were obtained, the percent waste, cost of waste, cost of production time, and cost of delivery time in January and August of 2011, 2014, and 2018 were compared to evaluate each batch schedule for operational efficiencies.

RESULTS

2011

In both January and August 2011 there were six batch prints with a print update before each delivery time (table 2).

Table 2: January and August 2011 Batch Production and Delivery Schedule

Batch print (General, Injectable, Oral liquids)	Print update (General)	Batch Print (Central IV)	Delivery time	Medication due
6:00am	9:30am	5:45am	11:00am	12pm-3:59pm
12:00pm	1:15pm	9:45am	2:30pm	4pm-6:59pm
2:00pm	3:30pm		5:30pm	7pm-9:59pm
6:30pm	8:00pm	4:45pm	9:30pm	10pm-1:59am
9:00pm	10:30pm	8:15pm	12:00am	2am-6:59am
11:30pm	3:45am	11:45pm	6:30am	7am-11:59am

62,668 total doses printed in the batch in January 2011. 11,014 (17.58 %) of these doses were not administered to the patient, therefore assumed to be wasted. The cost of the wasted medications totaled $135,230.50. 1215.44 technician hours were spent producing all 62,668 doses. With an average salary of $15 per hour, $18,231.60 was spent in technician salary for production time. 1152.72 hours were spent delivering batch medication to each bedside, costing $17,290.

53,092 doses printed in the batch in August 2011. 8,527 (16.06 %) of these doses were wasted. The total cost of wasted medication was $111,548.42. 1022.05 technician hours were spent in production, costing $15,330.75. 1015 hours were spent delivering batch doses costing $15,234.30.

2014

In January 2014 there was a very similar batch scheduled with six batch prints and a print update before each delivery time (table 3).

Table 3: January 2014 Batch Production and Delivery Schedule

Batch print (General, Injectable, Oral liquids)	Print update (General)	Batch Print (Central IV)	Delivery time	Medication due
6:00am	9:30am	5:45am	11:00am	12pm-3:59pm
12:00pm	1:15pm	9:45am	2:30pm	4pm-6:59pm
2:00pm	3:00pm		5:30pm	7pm-9:59pm
6:30pm	8:00pm	4:45pm	9:30pm	10pm-1:59am
9:00pm	10:30pm	8:15pm	12:00am	2am-6:59am
11:00pm	3:45am	11:45pm	6:30am	7am-11:59am

48,939 total doses printed in the batch in January 2014. 6,923 (14.15 %) of these doses were wasted. The cost of the wasted medications totaled $42,248. 857.60 technician hours were spent producing all 48,939 doses. With an average salary of $15 per hour, $12,864 was spent in technician salary for production time. 854.16 hours were spent delivering batch medication to each bedside costing $12,812.40.

In August 2014 the batch production scheduled changed substantially to have different batch print times and frequencies depending on dosage form. Additionally, there were only five deliveries each day (table 4).

Table 4: August 2014 Batch Production and Delivery Schedule

Batch print (injectable, general)	Batch print (iv admixture)	Batch print (oral liquids)	Delivery time	Medication due
2am	11pm		6:30	8am-9:59am
4am				10am-11:59am
6am	5am	6am	10:30am	12pm-1:59pm
8am		9:30am		2pm-3:59pm
10am	9am		2:30pm	4pm-5:59pm
12pm				6pm-7:59pm
2pm			5pm	8pm-9:59pm
4pm	4pm			10pm-11:59pm
6pm		6pm	10:30pm	12am-1:50am
8pm		9:30pm		2am-5:59am
9:30pm	8pm			6am-7:59am

20,271 doses printed in the batch in August 2014. 3,372 (16.63 %) of these doses were wasted. The total cost of wasted medication was $53,919.99. 459.23 technician hours were spent in production, costing $6,888.45. 341.95 hours were spent delivering batch doses costing $5,129.25

2018

In January and August 2018 there were ten batch prints a day delivered six times daily (table 5).

Table 5: January and August 2018 Batch Production and Delivery Schedule

Batch print	Delivery time	Medication due
6:00am	9:30am	12pm-1:59pm
8:00am		2pm-3:59pm
10:00am	1:30pm	4pm-5:59pm
12:00pm		6pm-8:59pm
2:00pm	5:30pm	9pm-9:59pm
4:00pm		10pm-11:59pm
6:00pm	10:00pm	12am-2:59am
8:00pm		2am-5:59am
10:00pm	11:30pm	6am-7:59am
12:00am	6:00am	8am-11:59am

29,917 total doses printed in the batch schedule in January 2018. 3,502 (11.71 %) of these doses were wasted. The cost of the wasted medications totaled $56,257.72. 526.35 technician hours were spent producing all 29,917 doses. $7,895.25 was spent in technician salary for production time. 636.25 hours were spent delivering batch medication to each bedside costing $9,543.75.

28,065 doses printed in the batch in August 2014. 3,641 (12.97 %) of these doses were wasted. The total cost of wasted medication was $61,465. 487.28 technician hours were spent in production, costing $7,309.20. 602.53 hours were spent delivering batch doses costing $9,037.95.

Table 6: Summary of Results

Operational Efficiencies in Batch Production										
Year	Month	Batch doses	Doses wasted	% doses wasted	Cost of wasted doses		Production Time (hours)	Production Cost	Delivery Time (hours)	Delivery Cost
2011	January	62,668	11,017	17.58%	$135,230.50		1215.44	$18,231.60	1152.72	$ 17,290.80
	August	53,092	8,527	16.06%	$111,548.42		1022.05	$15,330.75	1015.62	$ 15,234.30
2014	January	48,939	6,923	14.15%	$42,248.49		857.6	$12,864.00	854.16	$ 12,812.40
	August	20,271	3,372	16.63%	$53,919.99		459.23	$6,888.45	341.95	$ 5,129.25
2018	January	29,917	3,502	11.71%	$56,257.72		526.35	$7,895.25	636.25	$ 9,543.75
	August	28,065	3,641	12.97%	$61,465.42		487.28	$7,309.20	602.53	$ 9,037.95

Figure 1. Percent Drug Waste at six points in time

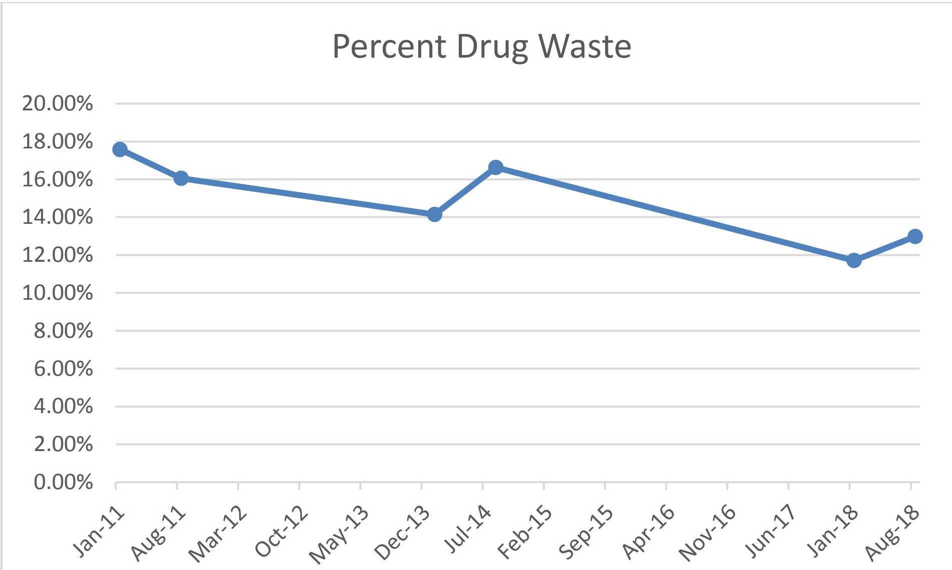
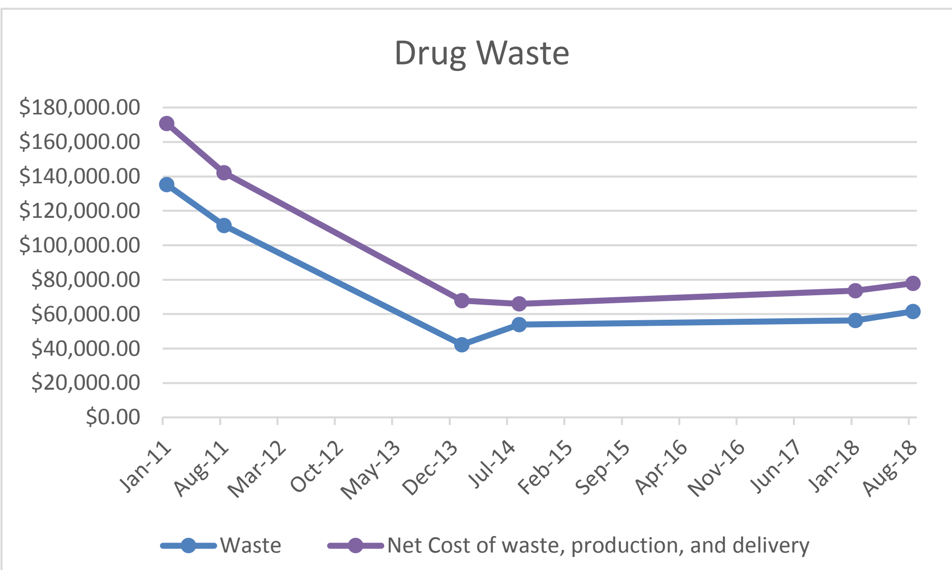


Figure 2. Drug waste in dollars at six points in time



DISCUSSION

Operational changes throughout the years have made batch production more efficient as seen by the reduction in portion of doses wasted and the cost associated with the wasted medications (figure 1 and 2). Drug waste from batch production decreased from 17.58% to 12.97% over the time examined. This is below the lowest percent of waste found in the literature of 18%. The experience outlined here confirms that the more frequent batch print, closer to the due time, results in less drug waste.

In examining the cost of drug waste throughout the years, the first large shift can been seen between August 2011 and January 2014. In August 2011 Corticotropin IM gel (H.P. Acthar® Gel), darbepoetin Alfa, treprostinil inhalation, nicardipine continuous infusion, and growth hormone (Nutopin AQ®) were some of the most expensive wasted batch medications; however, these do not appear in January 2014 wasted medications. Between this time, high-cost medications were removed from the batch to be prepared in the satellites "last minute" for several reasons including cost, the implementation of a trigger fill system for continuous IV, and change in clinical practice.

A second large shift can been seen in preparation time and cost between January 2014 and August 2014 due to the number of dosing being prepared. During this time period, a large amount of the batch production, all oral solids, was moved out of the central pharmacy batch process to a different satellite pharmacy. Because of this, the total number of doses prepared in the batch decreased from 49,000 to 20,000. The cost associated with waste, preparation, and delivery of oral solids was removed from the central batch data reviewed after January 2014 and not accounted for in the later time periods.

A large operational change occurred between January and August 2014. The batch production schedule went from six to eleven batch prints for injectable medication and the delivery schedule went from six to five deliveries. One would expect the production time to increase because of the increase in batch frequency; however, this is not seen because of such a large decrease in doses produced from the removal of oral solids from the batch. What is seen, is decreased delivery time and cost with the reduction of delivery frequency. In January 2014, 831 hours were spent delivering to the bedside while in August 2014 only 341 hours were spent. The normal cyclic nature of hospital admissions should be taken into account here as well, there were fewer bedsides to deliver to in August 2014 because fewer children were in the hospital, however it can be reasonably concluded that reducing just one delivery a day can save a substantial amount of time and money.

Despite reducing percent drug waste and removing multiple high-cost medications and oral solids from the batch doses evaluated here, a slight increase in dollar amount wasted can be seen in the more recent years. This could possibly be attributed to the well-known general increase in drug cost[vi]. However, because the increase is small, it is important to take into account the particular medications that were wasted and ongoing hospital expansion, which could also contribute to this increase over this portion in time.

Overall, removing high-cost medication from batch production as well as increasing production frequency has the most substantial effect on waste reduction. When considering these interventions it is important to note staffing and inventory restraints. Throughout the years, a substantial amount of the production moved out of the central batch pharmacy to the satellites, shifting the work to a more just in time production schedule not accounted for here. With the reduced number of doses in the batch the staff was able to become more efficient in production and delivery time, however not all pharmacy departments will be able to shift work in this way. Hospital pharmacy departments need to continually optimize their operations by regularly evaluating medications produced in the batch, batch frequency, and production and delivery time to become more efficient in this climate of rising medication cost.

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