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Saving Time under Pressure: Effectiveness of Standardizing Pediatric Resuscitation Carts

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ABSTRACT

BACKGROUND: Resuscitation situations are high risk and high stress, and delays in care can have significant influences on outcomes. Standardization of care protocols and equipment is postulated to decrease some of the stress and risk. The objective of this study was to document increased efficiency in finding resuscitation equipment in a standardized resuscitation cart.

METHODS: A new standardized resuscitation cart design was created, and a multimedia education program addressing the new design was launched. A goal was set to find required equipment in <15 seconds. Five cohorts of 10 nurses were timed at finding randomly chosen items 1, 12, 49, 152, and 351 days after new cart launch. *t* tests were used to compare estimated acquisition times of requested items using the new cart system to the old cart system (baseline), and a separate regression analysis was used to model skill degradation.

RESULTS: All pairwise comparisons showed significant decreases in mean acquisition time compared with baseline. One day after launch, the mean time to find items was reduced by 46%. Mean time to find requested items was below the goal of 15 seconds 12, 49, and 152 days after launch. This effect was lost by 351 days from launch. Regression analysis predicted the time to find items would exceed 15 seconds 287 days after launch.

CONCLUSIONS: Standardizing the resuscitation cart design greatly reduced time to find items and was accomplished with reduced financial cost. Skill degradation did occur over time, and refresher training was required.

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Pediatric resuscitations outside of emergency departments or ICUs are high-stakes, high-stress situations that require standardized protocols and equipment to increase the chance of successful outcomes.¹ Resuscitation systems that are color-coded and length based have made a significant impact on resuscitation standardization.² These systems have documented significant ease of implementation, as well as end-user satisfaction with the system.² Although a color-coded, length-based resuscitation system has been documented to be effective, implementing such a system comes with significant financial outlays. This initial cost outlay was prohibitive to our health care system, and a different approach to resuscitation cart standardization was necessary. The system in place at our institution was somewhat haphazard. Required equipment items were assigned to certain cart drawers, but there was limited organization and standardization of item location within the drawers. It was hypothesized that this lack of standardization would lead to delays in care specifically from inability to locate necessary items during a resuscitation situation. Rousek and Hallbeck showed that medication management during resuscitations could be improved through human factors engineering.³ They created a prototype medication drawer for their resuscitation carts that relied on standardized medication positioning and a system in which medications were easily visualized.³ This redesigned drawer significantly reduced the time it took to find medications and resulted in less waste of medications as well.³

We hypothesized that using the Lean tool known as 5S (Sort, Set, Shine, Standardize, and Sustain) would allow us to completely redesign a resuscitation cart, which would be efficient and could be achieved at a significant cost reduction compared with proprietary systems.⁴ We wanted a highly visual, standardized system that would allow items to be identified within 15 seconds of request. Additionally, we wanted to assess the degradation of skill in locating items over time and determine the optimal timing of refresher training on resuscitation cart equipment.

METHODS

Setting

This study was set in a 62-bed non-freestanding children's hospital in central Kentucky with a mean annual admission volume of 6962 admissions, resulting in an annual mean of 21 299 bed-days of patient care. Our facility incorporated a rapid response system in 2009 that reduced the cardiopulmonary arrest rate outside of the PICU from 19 events per 100 000 bed-days to 5 events per 100 000 bed-days over the course of 5 years.^{5,6} Reducing the number of cardiopulmonary arrest outside of the ICU, although a safety success for the patients, gave the medical staff fewer and fewer opportunities to access the resuscitation carts. This led to a decrease in familiarity with the layout and contents of the resuscitation carts.

Additionally, working in a children's hospital within a larger general hospital offers several unique challenges to the care of pediatric patients. In our facility, procedural areas provide care for both adults and children; this lack of pediatric-specific resources, as one would find in a stand-alone children's hospital, potentially increases the risk to deteriorating children. One method to alleviate some of the risk related to resuscitation of children was to standardize and optimize the contents and the layout of pediatric resuscitation carts.

Intervention

In January 2010, a multidisciplinary group composed of physicians, nurses, technicians, and pharmacists met to perform the 5S process with the overarching goal of creating a cart that contained necessary items for the first 15 minutes of a resuscitation. Equipment lists were reviewed and the final list decided by consensus. Drawer organizers for each cart drawer were purchased at a cost of \$40 per cart. Itemized equipment lists for each drawer were compiled, and final contents of each drawer were arrived at by consensus between the multidisciplinary team members. These items were then sorted into their individual compartments based on common themes such as medications, vascular access, and airway equipment, for example. Individual

equipment drawers were then organized into workable, standard layouts, separated by compartment organizers. The outsides of the individual compartments were labeled with general contents labels. Pictures of a representative drawer in both the old and the new system, as well as the labeled exterior of the cart, are shown in Fig 1.

The complete layout was photographed and coupled to an itemized equipment list to facilitate Materials Management production of the standardized carts. This atlas would also facilitate replenishment of carts after they were used. A spare cart was stocked and stored in Materials Management. When a cart was used for a patient, the replacement cart was delivered to the floor while the used cart was brought back to Materials Management and restocked according to the picture atlas.

The new standardized resuscitation cart had a planned launch of January 2011. Three months before the planned launch of the new resuscitation cart, a system-wide education effort was undertaken. The development team provided live training at monthly nursing staff meetings, as well as faculty and house staff meetings with a full-size prototype cart. This allowed members to get hands-on training with the new resuscitation cart design. A Web-based training module was created and launched to the nursing staff with the expectation of completing the Web-based module by the launch of the new resuscitation cart system. A picture atlas of the cart design was created and electronically distributed to all nursing, physician, and technician staff members who worked in areas that housed pediatric resuscitation carts; this picture atlas is included in the Supplemental Information. A printed version of the same atlas was created for Materials Management to facilitate production of the carts. In addition to the educational materials, the expectation of finding requested items in ≤ 15 seconds was distributed to all care providers.

To ensure a random selection of cart items to acquire, the list of cart supplies were sequentially numbered, and a random

FIGURE 1 A, Representative sample drawer of syringes, needles, and defibrillation pads in the old version of the resuscitation cart. B, Photograph of the same drawer and materials after reorganization in the new resuscitation cart system. C, Photograph of exterior labels on resuscitation cart drawers.

number table was used to select 15 items from this list. The names of each of these items was placed on an index card and laid face down in a 3×5 grid. Subjects then selected a card and showed it to the investigator, who removed it from the array. The subject was shown the item on the card and proceeded to find the item in the cart while being timed with a stopwatch. This process was repeated 2 more times for a total of 3 items per subject.

Multiple cohorts of nurses were chosen as test subjects from January 2011 to January 2012. A convenience sample of the 10 registered nurses scheduled for duty on the acute care inpatient unit of the children's hospital represented the subject population and were tested on finding items 1 day before the new resuscitation cart launch (D−1), 1 day after the resuscitation cart launch (D+1), and at various times

after launch. Because of a scheduling coincidence, the same nurses were scheduled on D−1 and D+1; these 2 cohorts of nurses represent a paired sample. Additional cohorts of acute care unit nurses were tested 12, 49, 152, and 351 days after launch of the new resuscitation carts. In total, 5 cohorts of 10 registered nurses each were asked to find 3 randomly selected items; times to find each individual item were recorded. Study data were collected and managed using REDCap electronic data capture tools hosted at the University of Kentucky. REDCap (Research Electronic Data Capture) is a secure, Web-based application designed to support data capture for research studies, providing (1) an intuitive interface for validated data entry, (2) audit trails for tracking data manipulation and export procedures, (3) automated export procedures for seamless data downloads to

common statistical packages, and (4) procedures for importing data from external sources.⁷

Data Analysis

Each nurse contributed 3 observations, and the average of these times was taken to statistically account for the possibility of clustering. *t* tests were used to compare estimated mean acquisition times of the new cart system to the baseline old cart system. *t* tests were 2-sided at the 5% significance level and used the Kenward and Roger approximation.⁸ A multivariate linear regression model, accounting for the paired observations from nurses on D−1 and D+1, was used to test for changes in mean acquisition times within a single-model framework. The time period from D+49 through D+351 was chosen to model skill degradation via a separate linear regression model that treated time as

linear. Analyses were conducted in SAS Version 9.3 (SAS Institute, Cary, NC).

Human Subject Protection

The Medical Institutional Review Board of the University of Kentucky reviewed and exempted this study protocol.

RESULTS

The financial cost for the transition to the new standardized system was \$40 per cart for the dividers; this resulted in a total cost of \$680 for all 17 resuscitation carts. Baseline testing on the old system, performed on January 26, 2011, showed a mean acquisition time of 30.34 seconds (95% confidence interval [CI]: 17.99–42.68); this served as the referent group for all comparisons. All resuscitations carts were sequentially converted to the new system on January 27, 2011. Materials Management prestaged all the necessary equipment in their facility on January 26, 2011, to allow for a smooth transition of new cart equipment. Each cart took ~60 minutes to remove old equipment, install dividers, replace equipment in the proper cell, attach drawer labels, perform a final quality inspection, and deliver the cart to the appropriate unit. Cohorts of nurses were tested again, starting 1 day after launch; these results are shown in Table 1.

There was a marked decrease in estimated mean acquisition time from 30.34 seconds with the old system to 16.41 seconds with the new system (95% CI: 8.98–23.83; $P = .03$). Estimated mean acquisition times decreased to 13.40 seconds by D+12 (95% CI: 6.71–20.08; $P = .02$), with the quickest acquisition time of 9.92 seconds noted 49 days after the launch of the new

resuscitation cart (95% CI: 6.36–13.48; $P = .005$). After this point, acquisition times began to increase through D+152 where the mean acquisition time was 12.13 seconds (95% CI: 8.53–15.73; $P = .009$). By 351 days after the launch of the new resuscitation cart, mean acquisition times were above the project's intended goal of ≤ 15 seconds. When the full cohort was analyzed at D+351, the estimated mean acquisition time again increased to 19.78 seconds (95% CI: 10.25–29.31; $P = .14$). A single outlier of 50.94 seconds was noted in this cohort. When this cohort was reevaluated with the outlier removed, the mean acquisition time decreased to 16.32 seconds (95% CI: 10.12–22.51; $P = .02$). These results are shown in Fig 2.

Linear regression was used to model longitudinal skill degradation by comparing changes in estimated mean acquisition times over the course of the study period. The results of the regression analysis are shown in Fig 3. Starting from the point of estimated maximum efficiency in acquiring items (D+49) through D+351, the model predicted a linear deterioration of acquisition times. By 287 days from new cart launch, estimated mean acquisition times rose to 15 seconds.

DISCUSSION

We documented that a well-designed, standardized resuscitation cart can dramatically aid in the efficiency of resuscitation operations without significantly increasing cost. Through visual control, robust education, and standard location of cart contents, the estimated mean item acquisition times were reduced by 46% compared with the old version of the

FIGURE 2 Box plot of acquisition times across the various study cohorts. Median acquisition times are represented by the solid horizontal bars, and interquartile ranges are shown by the boxes. On the “Days From Launch” axis, –1 represents the day before the new cart system launch, and all positive numbers represent days after launch of the new cart system.

carts. These findings are analogous to those demonstrated by Rousek and Hallbeck that standardization and human factors engineering can dramatically improve performance of resuscitation system components.³ Our study extrapolated their findings to an entire resuscitation cart, not just a single drawer. On D+1, only 40% of those tested admitted to receiving training on the new resuscitation cart. The nurses in the original paired cohort stated the external labeling of the drawers alone was impactful enough to reduce the item acquisition times. A stable, reliable platform was able to be created without a significant financial investment.

The opportunity cost of creating the nonproprietary system was the investment in ongoing education to maintain competency in acquiring items from the cart. The initial education, as well as ongoing emphasis during the initial phases of rollout most likely affected the decrease in acquisition times. The entire nursing staff completed the Web-based training by 6 weeks after the launch of the new standardized system. This coincided with the most efficient acquisition times, which likely represents effective training of a

TABLE 1 Results From the Time Trials (in Seconds) Comparing Old Resuscitation Cart Design to the New Design Over Time

Days From Launch	Mean (s)	Median (s)	SD (s)	95% CI (s)	P
D–1	30.34	27.37	17.26	17.99–42.68	Referent
D+1	16.41	15.98	10.37	8.98–23.83	.03
D+12	13.40	11.28	9.34	6.71–20.08	.02
D+49	9.92	9.35	4.98	6.36–13.48	.005
D+152	12.13	13.93	5.03	8.53–15.73	.009
D+351 with outlier	19.78	13.85	13.33	10.25–29.31	.14
D+351 outlier removed	16.32	12.90	8.06	10.12–22.51	.02

A single outlier of 50.94 s was noted in the D+351 cohort. Statistical analyses were performed with and without the outlier included.

FIGURE 3 Linear regression model of skill degradation over time. Each point represents the mean acquisition time for an individual nurse to find 3 random items from the resuscitation cart. Starting from the point of maximum efficiency at D+49, linear degradation of skill, as evidenced by increasing estimated mean acquisition times, was noted through D+351, with times equaling 15 seconds at 287 days after launch.

critical mass of providers with the new system. Because there was such an emphasis placed on resuscitation cart education and familiarity, a significant Hawthorne effect is most likely present. At the time the new resuscitation system was launched, resuscitation cart refresher training was held on an annual basis. Data from this project suggest that annual refresher training is inadequate to maintain the skill and competency needed to find items in an appropriate time span. Exploratory linear regression analysis based on our data, assuming a constant daily increase in mean acquisition time from day 49, showed that skill degradation was estimated to be equal to the goal of 15-second mean acquisition time 287 days after the new carts were launched. At a minimum, refresher training is required every 9 months to maintain competency with the system.

Several limitations were noted in this study. A stable platform for resuscitation equipment was created; however, it requires a modification to the typical annual education cycle that nurses in our facility undertake. As

previously mentioned, skills training occurs on an annual basis, whereas our data suggest that skill degradation, as defined as a mean acquisition time >15 seconds, occurs before the 1-year renewal period. To maintain competency, resuscitation cart training should occur no less frequently than every 9 months. A second noted limitation was that the new resuscitation system was only tested within inpatient units of the children's hospital. There were no clinics or ancillary service areas tested during this project. Although our system seems to be highly functional within the inpatient setting of the children's hospital, we cannot comment on its generalizability to other patient care areas. Testing the new platform within various clinics and ancillary clinical care areas would be warranted.

Although statistically significant results were obtained during the study, it is uncertain that this is a true predictor of function during an actual resuscitation. The implementation of a rapid response system at our hospital has reduced the incidence of cardiopulmonary arrest outside of the ICU from 19 events per 100 000 bed-days to 5 events per 100 000 bed-days.^{5,6} This reduction in cardiopulmonary arrests reduces the opportunity for staff members to get hands-on experience with the resuscitation cart system.

Finally, there was not a head-to-head comparison of efficiency and end-user satisfaction between our nonproprietary system and a color-coded, length-based resuscitations system. Agarwal documented that 67% of users preferred the proprietary system, but the acquisition times were longer in that study compared with those documented in our study.² Similarly, their group documented 99% effectiveness in finding appropriate items, whereas our study documented 100% effectiveness in finding requested items.² A head-to-head comparison of the 2 systems should show whether one is superior to the other.

In conclusion, a nonproprietary, standardized, visually controlled resuscitation cart system is capable of reducing the time to acquire requested items. It also allows for minimal investments in materials and equipment.

Education is a critical component of competency maintenance.

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