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Gamification educational intervention improves pediatric nurses' comfort and speed drawing up code-dose epinephrine

Caitlin E. King [a], Amanda Kells [a], Lindsay Trout [a], Alison Yirinec [b], Shouhao Zhou [c], Adrian D. Zurca [a,*]

[a] Penn State Children's Hospital, 500 University Dr., Hershey, PA 17033, United States of America
[b] Penn State College of Medicine, 500 University Dr., Hershey, PA 17033, United States of America
[c] Penn State School of Public Health Sciences, Division of Biostatistics and Bioinformatics, 700 HMC Crescent Road, Hershey, PA 17033, United States of America

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ABSTRACT

Purpose: Drawing up weight-based doses of epinephrine is a vital skill for pediatric nurses; however, non-intensive care unit (ICU) nurses may not routinely perform this skill and may not be as efficient or comfortable doing so during pediatric resuscitations. This study aimed to evaluate the impact of a gamification program on non-ICU pediatric nurses' knowledge and skills regarding epinephrine for pediatric cardiac arrest.

Design and methods: Comfort and time to draw up three doses of epinephrine during out-of-ICU in-hospital pediatric cardiac arrest were measured pre- and post- a gamification-centered educational intervention.

Results: Nursing comfort improved from 2.93 ± 1.90 to 6.68 ± 1.46 out of 10 (mean difference 3.6 +/− 2.1, $p < 0.001$). Overall time to draw up three doses of epinephrine decreased after the intervention by an average of 27.1 s ($p = 0.019$). The number of nurses who could complete the task in under 2 min improved from 23% to 59% ($p = 0.031$).

Conclusions: At baseline few non-ICU nurses could draw up multiple weight-based doses of epinephrine in under two minutes. A gamification simulation-based educational intervention improved pediatric non-ICU nurses' comfort and speed drawing up epinephrine.

Practice implications: Wide-spread implementation of gamification-centered educational initiatives could result in faster epinephrine administration and improved mortality rates from in-hospital pediatric cardiac arrest.

Introduction

Delaying epinephrine administration by even a few minutes is associated with worse survival rates and poorer neurologic outcomes for hospitalized children (Andersen et al., 2015; Hansen et al., 2018; Raymond et al., 2019). Unfortunately, up to 15% of hospitalized patients do not receive a dose of epinephrine in the first five minutes of cardiac arrest (Andersen et al., 2015), with delays in epinephrine administration most commonly seen in non-intensive care unit (ICU) settings and at smaller institutions (Andersen et al., 2015). Epinephrine is weight-based in pediatrics, requiring nurses to draw up patient-specific doses during high-stress low-frequency situations, risking medical errors (Brune et al., 2019; Kanwar et al., 2010). Tools such as cognitive aids have been used to decrease dosing errors but have not been shown to improve efficiency (Brune et al., 2020).

Medication errors are common in pediatric patients, and education is the most common type of intervention studied to improve outcomes (Marufu et al., 2022). Gamification is an educational technique that uses gaming elements such as problem-solving and environmental constraints to engage learners and help individuals accomplish a goal (Nevin et al., 2014). Gamification has been applied in medical education to improve hand-washing compliance (Lapao et al., 2016) and improve knowledge retention (Nevin et al., 2014), and has been found to improve nurses' motivation and engagement with educational objectives (Castro & Gonçalves, 2018; García-Viola et al., 2019; Malicki et al., 2020; Márquez-Hernández et al., 2019; Woolwine et al., 2019). The advantage of gamification is that the competitive nature of it can increase learner engagement and encourage practice compared to other traditional teaching methods (Kiryakova et al., 2014). There is a lack of studies investigating gamification for teaching cardiac arrest-based skills. We hypothesized that a gamification-based intervention would lead to an improvement in non-ICU nurses' speed and comfort level drawing up weight-based, code-dose epinephrine to improve outcomes for in-hospital out-of-ICU pediatric cardiac arrests.

* Corresponidng author.
E-mail addresses: akells@pennstatehealth.psu.edu (A. Kells), ltrout1@pennstatehealth.psu.edu (L. Trout), ayirinec@pennstatehealth.psu.edu (A. Yirinec), szhou1@phs.psu.edu (S. Zhou), azurca@pennstatehealth.psu.edu (A.D. Zurca).

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Methods

Aims

The primary aim was to decrease the time pediatric nurses needed to draw up three doses of epinephrine for in-hospital out-of-ICU cardiac arrest. The secondary goal was to evaluate non-ICU nurses' baseline comfort and skills drawing up weight-based doses of epinephrine.

Study design and sample

This was a prospective study that recruited non-ICU nurses in a tertiary care children's hospital in the United States. All the primary nurses from one clinical nursing unit were invited to participate. The research team presented the study to the nurses on the unit in person via previously planned staff meetings. All nurses also received emails regarding the study via email.

Data collection

Due to lack of appropriate previously existing surveys, de novo survey tools were developed to measure nurses' experiences, knowledge and comfort with epinephrine. The surveys were developed by the research team, which represented a multidisciplinary team of physicians, nurses and pharmacists with experience in pediatric resuscitation and medical education. The surveys were piloted by a small group of five experienced pediatric ICU nurses, with feedback and revisions made as needed. The surveys are available as Supplementary Material. A benchmark goal time of less than two minutes was determined by timing five experienced pediatric ICU nurses completing the task (range 69–104 s), which was also consistent with current resuscitation guidelines (Neumar et al., 2017). These nurses also provided feedback to help inform the procedure for timing, development of the step-by-step guide (Fig. 1) and educational phase of the study.

Baseline measurements included pre-intervention surveys assessing comfort level and knowledge basis and time to draw up three weight-based doses of epinephrine. Study team members trained in the timing procedure were available at various times of day and night to ensure all eligible nurses had the opportunity to participate. All the baseline times were measured by study team members and were included for analysis as pre-intervention times. For timing, nurses chose a card at random from a set of cards with various patient weights and then used that weight to draw up the doses. Baseline times were recorded for each individual dose and for total cumulative time to draw up three doses. Immediately after obtaining baseline times, an educational intervention consisted of immediate feedback and coaching where participating nurses repeated the task under the direct supervision of experienced nurse educators, using a step-by-step guide designed to provide nurses with time-saving tips (Fig. 1). The nurse educators were all nurses with experience working in the pediatric ICU and had at least three years of experiences responding to pediatric code blue events.

The gamification phase consisted of an eight-week period during which a training station with necessary supplies to draw up weight-based doses of epinephrine was available in clinical areas. During this time, the training station was available to the unit nurses at all times of day and night for them to practice. Nurses received regular communications encouraging them to practice with the goal of completing the task within two minutes.

After the gamification phase, a final four-week testing phase of the study ensued, where study team members were again available at various times of day and time to time nurses performing the task. Participating nurses were also asked to complete post-intervention surveys at the time of their timing. A leaderboard was maintained during the testing period to alert nurses to the best times obtained. Nurses could practice indefinitely, but only official times recorded by the study team counted for the leaderboard. Nurses had the option of being re-tested as many times as they wanted until they were satisfied with the time they had achieved. For nurses who chose to be timed multiple times, the most recent time was used for analysis.

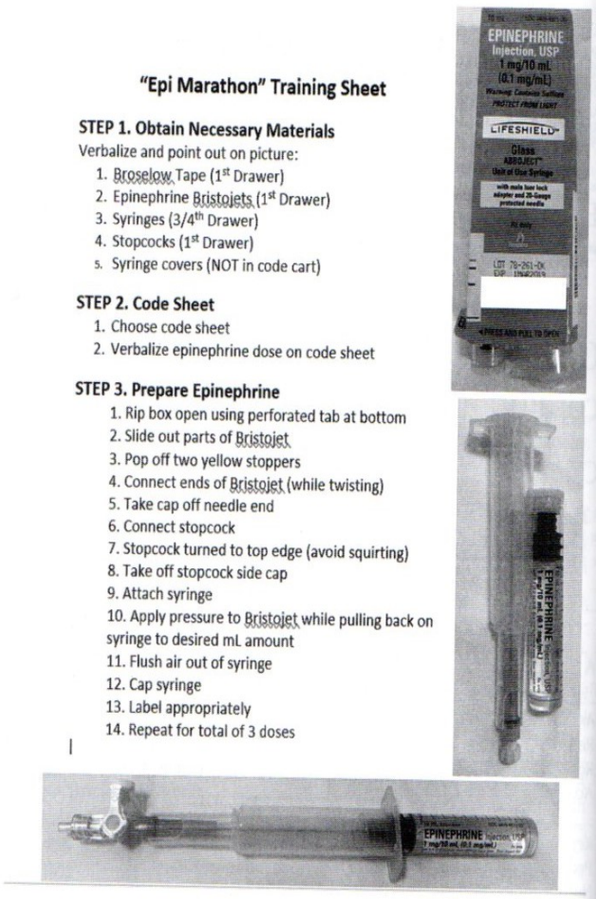

Fig. 1. "Epi Olympics" training sheet. This is an educational tool given to all participating nurses after baseline times were obtained.

Analysis

Descriptive statistics were used for demographic data. Paired *t*-tests were used to compare the changes in pre- and post-intervention times. The S and chi-squared tests were used for continuous and categorical variables, respectively. Spearman's rank correlation was applied to examine variable associations. Comfort was measured on a ten-point scale, with 10 being extremely comfortable and 0 being extremely uncomfortable. Wilcoxon rank sum test was used to compare the pre- and post-intervention self-reported comfort level. McNemar's test with continuity correction was applied to examine the change in knowledge. Analyses were conducted using statistical software R *v4.0.0* with packages ggplot2 *v3.3.0* and GGally *v1.5.0*.

Ethical consideration

This study was reviewed and approved as exempt by the institutional IRB on April 11, 2018 under study number 00009463. All participation in the study was strictly voluntary. Verbal consent was obtained from all nurses. All potential participants were provided with an information sheet regarding the study. Nurses were also offered the option of undergoing the educational component of the study without completing the surveys or being timed. Survey data was stored on paper and kept locked in a cabinet within a secure office so that only study team members had access to data.

Table 1
Demographics and Epinephrine Experience at Baseline ($n = 47$).

Years Experience, n (SD, range)	7 (±7.59, 0–32)
0–4 years of experience, n (%)	22 (47.8%)
5–9 years of experience, n (%)	10 (21.7%)
>10 years of experience, n (%)	12 (26.1%)
Actual codes participated in, n (SD)	5.88 (±6.09)
Simulated codes participated in, n (SD)	4.12 (±5.21)
Participated in 0 simulated codes, n (%)	7 (15.2%)
Participated in 1 simulated code, n (%)	7 (15.2%)
Times drawn up epinephrine in clinical practice, n (SD)	0.24 (±0.85)
Drew up epinephrine 1 time, n (%)	5 (10.9%)
Drew up epinephrine >1 time, n (%)	2 (4.35%)
Never drew up epinephrine for any reason, n (%)	20 (43.5%)
Pre-intervention time to draw up 3 doses, seconds (SD)	161 (±47.9)
Completed in under 2 min, n (%)	8 (18%)
Completed in under 3 min, n (%)	29 (68%)

Results

Forty-seven out of 51 eligible nurses completed the initial pre-intervention assessments (enrollment rate 92%). Demographic information and information regarding baseline nurses' experiences with epinephrine are presented in Table 1. Post-intervention assessments were obtained for 22 nurses (retention rate 43%) and only these were included in analyses comparing outcomes pre- and post-intervention. Demographic information for the initial cohort of nurses compared to nurses who completed the post-intervention assessment were similar (Supplemental Table 1).

Baseline assessment: time to draw up epinephrine

The mean pre-intervention time for 47 non-ICU nurses was 161 s (standard deviation 47.9). There was a significant association between time to complete the task and years of nursing experience (-0.45; $p = 0.002$) and number of code blue events previously attended (-0.46; $p = 0.002$), and no association with other prior experiences (Table 2).

Impact of intervention: time to draw up epinephrine

Analysis was then performed for the nurses who completed both pre- and post-intervention testing (Table 3). Prior to the intervention, 68% of nurses were able to draw up all three doses in <3 min, while only 23% were able to draw all 3 doses in <2 min. After the intervention, 91% of the participants were able to draw up all three doses in <3 min and 59% were able to do so in <2 min. The average total time to draw up three doses decreased from 147 (±47.0) seconds to 119 (±35.5) seconds ($p = 0.019$). For the individual doses, the decreases were from 79.9 s to 65.6 s ($p = 0.059$) for the first dose, 38.7 s to 33.6 s ($p = 0.12$) for the second dose, and 28.6 s to 20.1 s ($p = 0.027$) for the third dose.

Nurse epinephrine-related comfort and knowledge

Comfort level drawing up epinephrine for the 47 non-ICU nurses who completed the pre- intervention assessment did not correlate with the number of years of nursing experience ($\rho = 0.12$; $p = 0.43$), number of prior actual ($\rho = 0.24$; $p = 0.12$) or simulated code events ($\rho = 0.03$; $p = 0.84$). Table 3 details epinephrine-related comfort and knowledge for the 22 nurses for which pre- and post-intervention data was available. After the intervention, nurses' comfort improved from 2.93 (±1.90) to 6.68 (±1.46) points (maximum 10 points; mean difference 3.6 (±2.1), $p < 0.001$). Nurses were significantly more likely to know the correct concentration of epinephrine used for cardiac arrest after the intervention (19% to 73%; $p = 0.00067$). There was no significant difference in the number of nurses who could correctly recall the dose or location of epinephrine in the code cart.

Discussion

Gamification can be a helpful tool in nursing education (Malicki et al., 2020) and gamification interventions have been used to successfully teach practical skills to nurses (Malicki et al., 2020) and to improve quality of care in settings such as hygiene compliance (Lapao et al., 2016; Marques et al., 2017). In our literature review, gamification had not previously been applied to nurses drawing up medication doses. This study demonstrates that it can be an effective way of helping non-ICU nurses develop the skills to quickly and reliably draw up weight-based doses of epinephrine.

Faster administration of epinephrine improves survival for children suffering cardiac arrest (Andersen et al., 2015). The 2019 Pediatric Advanced Life Support (PALS) guidelines recommend epinephrine dosing after 2 min of cardiopulmonary resuscitation (Craig-Brangan & Day, 2019). In our study, at baseline, non-ICU pediatric nurses were uncomfortable drawing up epinephrine and had low baseline epinephrine-related knowledge. Although most nurses were unable to draw up three doses of epinephrine in less than two minutes before training, after a gamification-based educational intervention the majority were able to complete the task, with comfort level and epinephrine knowledge improving concomitantly.

However, even though the percentage of nurses who were able to meet the two-minute benchmark increased from 23% to 59%, we are concerned that this is not high enough and would plan to continue working with local leadership to further increase nurses' skills. Based on previous research and current PALS guidelines, we recommend a goal of non-ICU nurses being able to draw up three doses of epinephrine in less than two minutes to help optimize pediatric cardiac arrest outcomes. Nursing units should pay attention to ability to draw up weight-based doses of epinephrine, along with additional important life-saving skills such as bag-mask ventilation for respiratory failure and effective chest compressions, as important metrics when evaluating and maintaining nurses' clinical skills.

Further studies should aim to evaluate whether nurses' baseline low comfort level exists in other clinical units and hospitals, as the life-

Table 2
Association Between Baseline Demographic Characteristics, Experiences with Epinephrine and Baseline (Pre-Intervention) Time to Draw Three Doses of Epinephrine.

	Years of Nursing Experience	Actual # Cardiac Arrests	Simulated # Cardiac Arrests	Total # Times Epi Drawn Up	# Times Epi Drawn Up During Cardiac Arrest	Pre-Intervention Time to Complete Task
Years of Nursing Experience	–	0.82[a]	0.4[a]	0.05[a]	0.3[a]	-0.45[a]
Actual # Cardiac Arrests	<0.001[b]	–	0.41[a]	0.14[a]	0.33[a]	-0.46[a]
Simulated # Cardiac Arrests	0.009[b]	0.009[b]	–	0.19[a]	0.16[a]	-0.07[a]
Total # Times Epi Drawn Up	0.739[b]	0.384[b]	0.247[b]	–	0.5[a]	-0.22[a]
# Times Epi Drawn Up During Cardiac Arrest	0.055[b]	0.033[b]	0.326[b]	<0.001[b]	–	-0.17[a]
Pre-Intervention Time to Complete Task	0.002[b]	0.002[b]	0.677[b]	0.16[b]	0.277[b]	–

[a] Pairwise Spearman's correlation.
[b] Corresponding p-value of the Spearman's correlation.

Table 3
Nurses' Epinephrine Skills and Knowledge Before and After Gamification Intervention ($n = 22$).

	Pre	Post	P-value
Time to 1st Epi[a] dose, Mean seconds (± SD)	79.9 (±20.3)	65.6 (±15.4)	0.059
Time to 2nd Epi[a] dose, Mean seconds (± SD)	38.7 (±10.9)	33.6 (±10.3)	0.12
Time to 3rd Epi[a] dose, Mean seconds (± SD)	28.6 (±9.34)	20.1 (±7.93)	0.027
Total Time to Complete Task[b], Mean seconds (± SD)	147 (±47.0)	119 (±35.5)	0.019
Completed Task[b] in <3 min, n (%)	15 (68%)	20 (91%)	0.13
Completed Task[b] in <2 min, n (%)	5 (23%)	13 (59%)	0.031
Comfort Drawing Up Epi[a] (1–10; Max Comfort = 10)	2.93 (±1.90)	6.68 (±1.46)	<0.001
Knows Correct Epi[a] Concentration, n (%)	4 (18%)	16 (73%)	<0.001
Knows Correct Epi[a] Dose, n (%)	5 (23%)	8 (36%)	0.51
Knows Location of Epi[a] in Code Cart, n (%)	20 (91%)	21 (95%)	1

[a] Epi = Epinephrine.
[b] Complete Task = Draw up three weight-based doses of epinephrine.

saving potential of epinephrine when administered quickly during a code emphasizes the importance of improving the training of nurses to be prepared for in-hospital out-of-ICU cardiac arrest settings. Additionally, further studies should evaluate the impact of gamification-focused educational interventions on improvements in clinical care and the impact on actual patient outcomes.

Limitations

Though most of the nurses on this inpatient unit participated in the pre-intervention stage, 57% did not complete the post-intervention assessment which resulted in a small sample size and potential for selection bias. Though most of the nurses on this inpatient unit participated in the pre-intervention stage, not all returned for repeat timing post-intervention. This was likely due to high nursing turnover at the time and concern for compromising patient care. Those who did return for post-intervention timing may be more naturally competitive and therefore more likely to benefit from a gamification intervention. Long-term retention was not assessed and should be evaluated in future studies.

Implications for practice

While improvements were seen in every time metric, the greatest improvement was in drawing up the first dose. Prefilled syringes have been suggested for pediatric patients to improve this process (Kanwar et al., 2010), but this necessitates keeping more medications in the code cart which may expire before they are used. Additionally, having multiple individual doses of epinephrine available in a code cart may increase the risk of error. This study suggests that focused educational interventions can help non-ICU nurses develop the skills necessary to efficiently draw up weight-based doses of epinephrine using commonly existing equipment.

Conclusion

Baseline comfort level and efficiency in drawing up epinephrine was low in non-ICU pediatric nurses in this single-center study. Gamification intervention can improve comfort, knowledge and speed with which nurses can draw up three doses of epinephrine, which may lead to more efficient administration of epinephrine to pediatric patients during out-of-ICU in-hospital cardiac arrests.

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Disclosures

None.

CREDIT Statement

Caitlin E. King: Conceptualization, Methodology, Investigation, Writing – original draft, Visualization, Data curation, Project administration. **Amanda Kells:** Conceptualization, Methodology, Investigation, Writing – review & editing, Project administration. **Lindsay Trout:** Conceptualization, Methodology, Investigation, Writing – review & editing, Project administration. **Alison Yirinec:** Conceptualization, Investigation, Writing – review & editing. **Shouhao Zhou:** Methodology, Formal analysis, Writing – review & editing, Visualization. **Adrian D. Zurca:** Conceptualization, Methodology, Investigation, Resources, Writing – review & editing, Visualization, Supervision, Project administration.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pedn.2023.03.013.

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