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REPORTS OF ORIGINAL INVESTIGATIONS

Cognitive aids with roles defined (CARD) for obstetrical crises: a multisite before-and-after cohort study

Le système CARD avec rôles définis pour gérer les crises obstétricales : une étude de cohorte multisite avant/après

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Abstract

Purpose *Patient outcome during an obstetrical emergency depends on prompt coordination of an interprofessional team. The cognitive aids with roles defined (CARD) is a cognitive aid that addresses the issue of teamwork in crisis management. This study evaluated the clinical impact of implementing the CARD cognitive aid during emergency Cesarean deliveries.*

Methods *We conducted a prospective before-and-after cohort trial at the maternity units of two Canadian academic hospital campuses. Both sites received didactic online training regarding teamwork during crises, which involved training on using CARD for the "CARD" campus (intervention) and no mention of CARD at the "no CARD" campus (control). The primary outcome was the total time to delivery after the call for an emergency Cesarean delivery. Secondary outcomes included specific intervals of time within the time to delivery and clinical outcomes for both the babies and mothers.*

Results *We analyzed data from 267 eligible emergency Cesarean deliveries that occurred between January 11 2014 and December 31 2017. The use of CARD did not significantly change the median [interquartile range] time to delivery of the baby during an emergency Cesarean delivery from the pre-intervention to the post-intervention time period (17 [12–28] vs 15 [13–20], respectively; median difference, 2; 95% confidence interval, −1 to 5; P = 0.36). The clinical outcomes for the baby or the mother and other secondary outcomes also did not change.*

Conclusions *The CARD cognitive aid did not significantly improve time-based or clinical maternal and neonatal outcomes of emergency Cesarean delivery at our academic maternity unit.*

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Résumé

Objectif *Les devenirs des patientes pendant les urgences obstétricales dépendent de la coordination rapide d'une équipe interprofessionnelle. Le système CARD (Cognitive Aids with Roles Defined) est un outil de soutien cognitif qui est centré sur le travail d'équipe dans la gestion de crise. Cette étude a évalué l'impact clinique de la mise en œuvre d'un système CARD pendant les accouchements par césarienne d'urgence.*

Méthode *Nous avons réalisé une étude de cohorte prospective avant / après dans les services de maternité de deux campus hospitaliers universitaires canadiens. Les deux sites ont eu accès à une formation didactique en ligne portant sur le travail d'équipe pendant les crises; dans le campus « CARD » (groupe intervention), une formation sur l'utilisation du système CARD a été incluse, alors qu'aucune mention du système n'a été faite dans le campus « sans CARD » (groupe témoin). Le critère d'évaluation principal était le délai total jusqu'à l'accouchement après l'appel pour un accouchement par césarienne d'urgence. Les critères secondaires comprenaient les intervalles spécifiques de temps jusqu'à l'accouchement et les pronostics cliniques des bébés et de leurs mères.*

Résultats *Nous avons analysé les données de 267 accouchements par césarienne d'urgence éligibles survenus entre le 11 janvier 2014 et le 31 décembre 2017. L'utilisation du système CARD n'a pas modifié de manière significative le délai médian [écart interquartile] jusqu'à l'accouchement du bébé pendant un accouchement par césarienne d'urgence tel que mesuré entre le moment pré-intervention et le moment post-intervention (17 [12–28] vs 15 [13–20], respectivement; différence médiane, 2; intervalle de confiance 95 %, −1 à 5; P = 0,36). Les pronostics cliniques des bébés et des mères et les autres critères d'évaluation secondaires n'ont pas non plus été modifiés.*

Conclusion *Le système CARD n'a pas amélioré de façon significative les pronostics maternels et néonatals fondés sur le temps ou la clinique en cas d'accouchement par césarienne d'urgence dans notre service de maternité universitaire.*

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During a critical event, patient outcome may depend on prompt and coordinated action by an interprofessional team.[1,2] Task overload, overcrowding, and unclear definition of roles can impede teamwork efficiency during a critical event.[3–5] Life-threatening emergencies are frequent in healthcare[6] and represent a persistent challenge for interprofessional teams.[7–11]

One potential solution to facilitate teamwork in critical situations is the use of cognitive aids to lessen healthcare providers' dependence on memory.[12] Cognitive aids allow users to retrieve information more effectively[13–15] and typically appear as algorithms to quickly calculate appropriate doses of medication or a specific sequence of actions to take. Though useful for individuals and often employed by teams, these cognitive aids do not explicitly address the complex interactions of teams during critical situations.

The cognitive aids with roles defined (CARD) is a new type of cognitive aid for crisis management that focuses on clarification of distribution of tasks and individual roles instead of providing a treatment algorithm (i.e., list of actions or medications).[16] The CARD relies on large identification cards specially designed for each team member's profession and role. Each card worn by a team member identifies the tasks associated with that individual's role to the other members of the team and reminds its wearer of their assigned tasks. If someone responds to a code and does not have a card, they are asked to remain in the room, away from the patient, and wait for instructions from the code leader. The cognitive aid allows the code leader and team members to quickly identify who the other responders are, the roles of each team member, and to begin their pre-determined tasks immediately. The CARD is designed to reduce team members' mental workload during a crisis, freeing mental resources to focus on pre-assigned tasks. This may result in improved crisis resource management (CRM) performance of teams.

Our CARD1 pilot study found that multidisciplinary professionals were overwhelmingly in favour of instituting the CARD system[17] and that CARD clarified role definition, eliminated redundancy, and reduced task overload. Therefore, CARD was perceived to have the

potential to improve team performance during the response to critical events.[17] Nevertheless, CARD1 evaluated team performance in simulated intraoperative cardiac arrest rather than in clinical practice.[17]

Emergency Cesarean deliveries are, by definition, performed under time pressure and always involve an interprofessional team. Emergency Cesarean deliveries are highly stressful, partly because of the potential for significant harm to the mother and baby (e.g., death or permanent brain damage in otherwise healthy patients) and the expectation of good outcomes. A delay in delivery may increase the risk of maternal or neonatal morbidity or mortality, thus necessitating a well-coordinated team to optimize patient care. Also, while Cesarean deliveries are common within institutions, various individual healthcare providers may have infrequent exposure to them.

This study aimed to evaluate the influence of the CARD cognitive aid on processes of care and patient outcomes in clinical practice for emergency Cesarean deliveries at a large Canadian academic centre. Specifically, we compared clinical outcomes when implementing CARD during emergency Cesarean deliveries *vs* standard management with no CARD. Our primary hypothesis was that the CARD system would decrease the total time taken to deliver the baby. Secondarily, we hypothesized that it would also improve clinical outcomes for the mother and baby compared with traditional management without CARD implementation.

Methods

This study was approved on August 12 2013 by the Ottawa Health Science Network Research Ethics Board (Protocol #20120926-01H). The research ethics board waived the requirement for written informed consent because of the nature of the study. This study was a prospective cohort trial in which we used both historical and concurrent control groups. This study is reported according to the STROBE reporting guideline.[18]

We conducted the study at both maternity units (General and Civic campuses) of The Ottawa Hospital, which together deliver approximately 6,600 newborns each year. An average of one to two obstetrical crises (e.g., prolonged fetal heart rate deceleration) occur per week at each site.[19] At The Ottawa Hospital, any obstetrical crisis requiring the assistance of an anesthesiologist leads to a "code 333". A code 333 is an overhead call made in the hospital to activate an emergency response system. The code is initiated to trigger resuscitative measures in a mother and/or baby and also to accelerate the delivery of a baby deemed to be at high risk of demise.

Staff who normally respond to a code 333 (obstetricians, anesthesiologists, neonatal intensive care unit [NICU] respiratory therapists, obstetrical registered nurses, and NICU staff) participated in the study. We used a pragmatic educational intervention that occurred in the clinical setting in an academic hospital with multiple campuses. Post-graduate trainees were sometimes involved as per usual care and these trainees may have rotated between the two campuses; however, staff physicians and nurses work almost exclusively at only one of the two campuses.

Both sites received training on teamwork during emergencies via an interactive eLearning module. The eLearning module was created for this study and incorporated into the standard clinical training at The Ottawa Hospital for obstetrical care. The module was mandatory for new and existing staff. Two versions of the module were created: for participants at the "CARD" campus (serving as the intervention for the CARD implementation), the module covered both CRM skills and the CARD system, explaining the concept of the cards with examples and providing instructions on how to use them. At the "no CARD" campus (serving as a control for the CARD implementation), the module described CRM skills and did not mention CARD. Both modules included interactive quiz questions and lasted approximately ten minutes. The modules consisted of a PowerPoint® presentation and a video of a simulated scenario. Enrolment in the training module occurred before the intervention but after baseline data were collected, and lasted five months (between October 2016 and February 2017). Completion rates of eLearning modules were collected. The modules were offered to new staff through the end of 2017. Staff members were asked to complete the modules once; there was no refresher training. After the training period was completed at both sites, CARD was implemented at the "CARD" campus for code 333s while the "no CARD" campus continued without CARD (Fig. 1).

The CARD cards with their associated roles and list of tasks were specifically designed for code 333 using a modified Delphi approach[20] with volunteers from all professions actively involved in code 333s. An initial face-to-face meeting allowed the working group to create an initial draft of the cards and tasks. Then, an iterative refinement process ensued over email until 80% agreement on all items was obtained. The cards used in the study are included in the Appendix.

We prospectively collected data from patients' charts for all babies born during a code 333 at the obstetrical unit at both campuses. For each code 333 that led to an emergency Cesarean delivery being performed, we collected two sets of quantifiable outcomes—time-based data and patient-based clinical data.

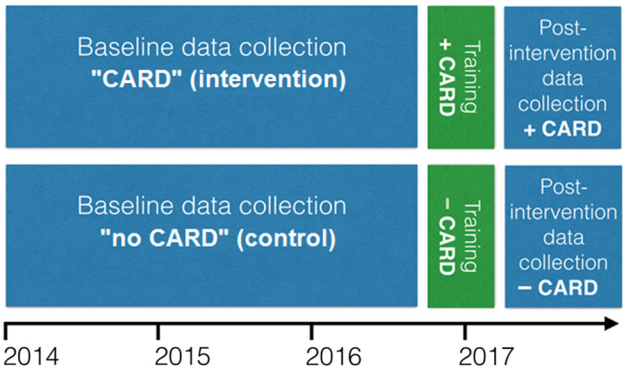


Fig. 1 Phases of the study. Both sites received an eLearning training module on crisis resource management. At the "CARD" campus this training also described the use of cognitive aids with roles defined, an aid which was then implemented at this campus.

The *time-based data* included the following: time the code 333 was called; time the patient arrived in the operating room (OR); time the surgical incision was made; and the time the baby was born. The time of the code 333 was electronically recorded at the central location of the hospital dispatching system; the other times were recorded by the nurses in the clinical charts.

The *patient-based clinical data* included the following outcomes. For *babies*, we recorded the Apgar score at one minute and five minutes, arterial cord blood pH at birth, rates of unplanned admission to the NICU, length of stay in hospital, and in-hospital mortality. For *mothers*, we collected the percentage of unplanned admission to the ICU, length of stay in hospital, and mortality. We collected the mother's age and whether the code 333 was called for a multiple birth. We also recorded the type of anesthesia used as it could affect the total time to delivery. In case of multiple births during the same code 333, only times and clinical data from the first baby born were included. Data of other babies (second and beyond) were excluded. Maternal cases were excluded if the medical records number was missing or if the delivery was vaginal.

The total time to delivery, defined as the number of minutes between the moment the code 333 was called and the birth of the baby, was our primary outcome measure. Our secondary outcomes included the intervals within the total time to delivery (Fig. 2) and patient-based outcomes.

Statistical analysis

We calculated our sample size *a priori*. Previous published data from The Ottawa Hospital reported a median time to delivery of 20 (7) min during a code 333.[19] In the absence of a citeable reference, a reduction in time to delivery of four minutes (20%) was considered to be clinically meaningful by the multidisciplinary co-investigator team.

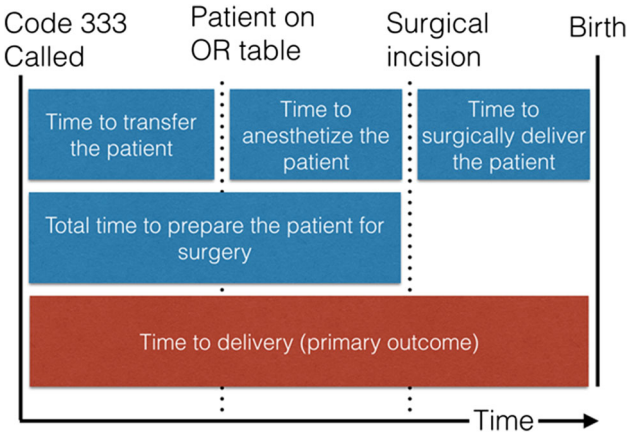


Fig. 2 Definitions of time intervals during emergency Cesarean deliveries. Time to delivery was our primary outcome. We also considered specific intervals within this time as secondary outcomes.

With a power of 0.80 and a two-tailed α of 0.05, we needed a total sample size of 90 code 333s in the post-intervention period to be able to show a four-minute reduction in delivery time.[21] Allowing for attrition, we aimed to enroll 100 patients undergoing a code 333 across the intervention and control groups. Based on previously published data from The Ottawa Hospital[19] and more recent unpublished data regarding code 333s at The Ottawa Hospital, we expected that we would need ten months after the intervention to reach our target sample size.

We tested for normality using the Shapiro–Wilk test; data were not normally distributed and were presented as median [interquartile range (IQR)]. We used Mann Whitney U tests (for continuous variables) and Chi square tests (for categorical variables) to determine whether there was a significant change between the baseline and the post-intervention period in each outcome measure at each campus. We used an α of 0.05 to determine significance. We used Mann Whitney U tests and Chi square tests to compare the two campuses at baseline and during the post-intervention period using the same outcome measures. We calculated the difference between population medians and 95% confidence intervals (CI) of the difference between medians using the Hodges–Lehmann estimator. We used a difference-in-difference estimation[22] in a multiple linear regression model to estimate the effect of the CARD intervention at the "CARD" campus. All statistical analysis was performed using SPSS Statistics, version 25.0 (IBM, Armonk, NY, USA).

Results

Completion rates of the online modules are presented in Table 1. Data were collected for a total of 346 babies born

Table 1 Completion of the eLearning module for staff healthcare professionals."CARD" Campus—crisis resource management eLearning module including CARD

	RNs	RTs	Maternal and fetal medicine physicians	Neonatologists	Anesthesiologists	OB/GYN physicians	Total
Completed	139	67	5	10	30	12	263
Total enrolled	143	68	7	12	35	12	277
Completed (%)	97	99	71	83	86	100	95
"No CARD" Campus—crisis resource management module without CARD							
	RNs	RTs	Maternal and fetal medicine physicians	Neonatologists	Anesthesiologists	OB/GYN physicians	Total
Completed	113	44	3	2	36	13	211
Total enrolled	116	47	3	2	38	13	219
Completed (%)	97	94	100	100	95	100	96

CARD = cognitive aids with roles defined; OB/GYN = obstetrics and gynecology; RN = registered nurse; RT = respiratory therapist.

The difference between completion rates by physicians at each campus was non-significant according to Chi square test for association (P = 0.053).

during 331 code 333s between January 11 2014 and December 31 2017. Seventy-nine maternal cases were excluded from analysis because of a missing maternal medical records number or because they were vaginal births. Fifteen babies were excluded because only the first baby was included in case of multiple births (Fig. 3). A total of 267 code 333s (i.e., 267 babies) were analyzed, 145 codes from the "CARD" campus and 122 from the "no CARD" campus. Of note, our post-intervention sample size achieved 77 subjects, which was below the 90 subjects anticipated: the rate of code 333s appeared to have declined since our sample size calculation and because of the resources required, we had to stop data collection before reaching our calculated sample size. Detailed demographic information per campus and study phase is presented in Table 2.

Primary outcome: total time to delivery

As for our primary outcome at the "no CARD" campus, the median [IQR] time to delivery decreased by three minutes (14 [9–18] min *vs* 11 [9–16] min; median difference, 2; 95% CI, 0 to 4; P = 0.15) and at the "CARD" campus the median time to delivery decreased by two minutes (17 [12–28] *vs* 15 [13–20]; median difference, 2; 95% CI, −1 to 5; P = 0.36). The difference-in-difference between the two campuses yielded a non-significant regression coefficient (ß = -3.9; 95% CI, −12.2 to 4.4; P = 0.36).

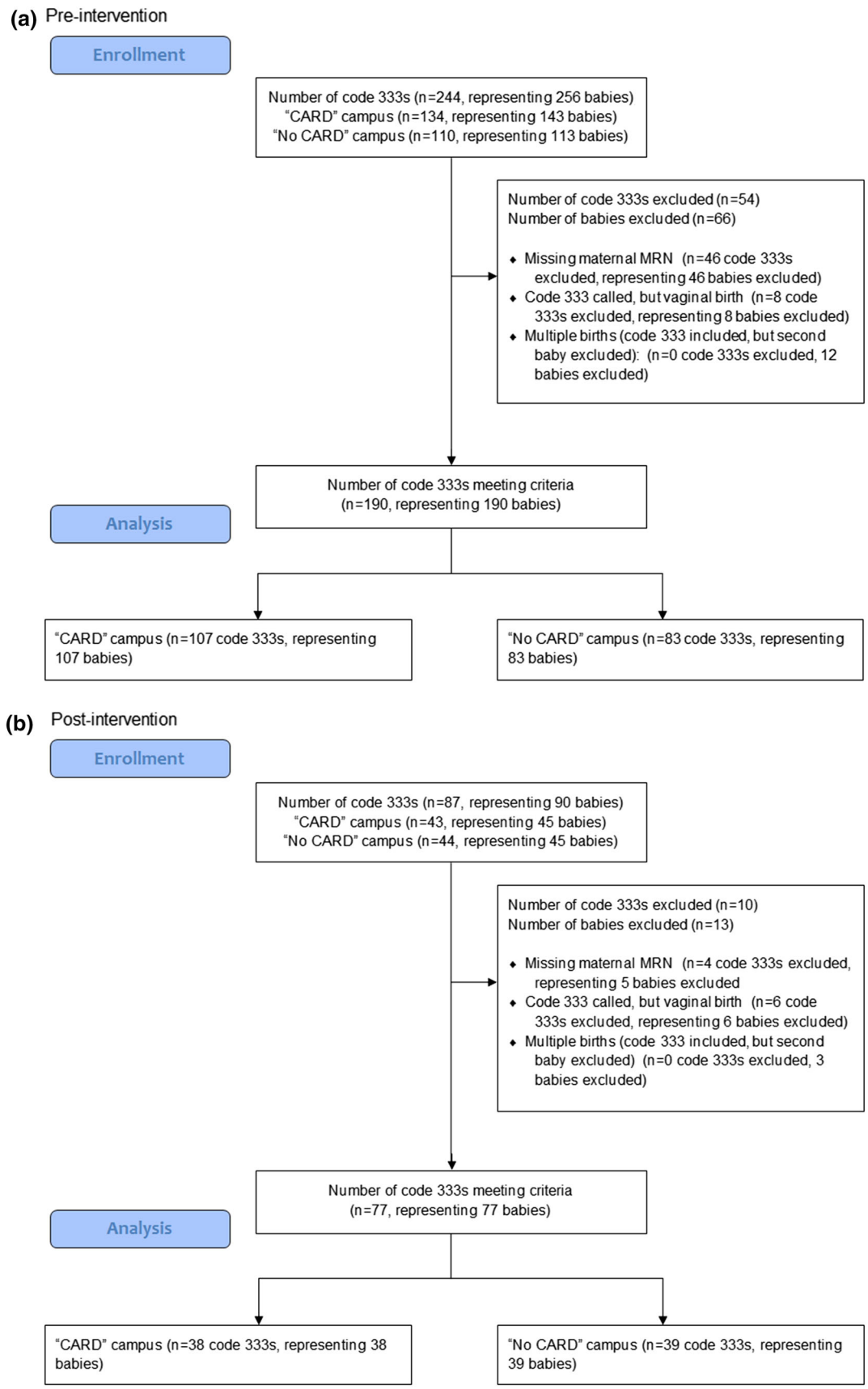
In the pre-intervention phase, the total median [IQR] time to delivery was significantly shorter at the "no CARD" campus *vs* the CARD campus (14 [9–18] *vs* 17 [12–28]; median difference, −4; 95% CI, −6 to −1; P = 0.004). In the post-intervention, the total time to delivery was significantly shorter at the "no CARD" campus *vs* the "CARD" campus (11 [9–16] *vs* 15 [13–20]; median difference, −4, 95% CI, −6 to −1; P = 0.006). Figure 4 presents the distribution of the total time to delivery at each hospital at the two phases.

Data for secondary time-based and clinical outcomes are reported in Table 3. The "no CARD" campus was faster than the "CARD" campus on several of the interim time intervals in both the pre- and post-intervention phases, which suggests that CARD was likely not responsible for this difference. Overall, no significant changes to clinical outcomes could reasonably be attributed to CARD.

Discussion

Our data showed no measurable impact on time-based and clinical outcomes related to the introduction of the CARD implementation for emergency Cesarean delivery. The present study suggests that the CARD system does not significantly reduce total time to delivery during a code 333 at an academic maternity unit. Therefore, our results do not support the tested intervention of eLearning with implementation of the CARD system for emergency Cesarean delivery.

We noticed a non-statistically significant change to the variability in time to delivery at both campuses, with a more visually pronounced effect in the "CARD" campus over time. Though not statistically significant, we also observed in the "CARD" campus a reduction of the number of patients whose delivery took longer than 30 min from 10 to 0; this indicates alignment with the historical standard of performing an emergency Cesarean delivery within 30 min of the decision to perform it.[23] Nevertheless, the reasons for these differences are unclear. Preliminary findings from our pilot study showed that CARD requires


(a) Pre-intervention
Enrollment
Number of code 333s (n=244, representing 256 babies)
"CARD" campus (n=134, representing 143 babies)
"No CARD" campus (n=110, representing 113 babies)
Number of code 333s excluded (n=54)
Number of babies excluded (n=66)
Missing maternal MRN (n=46 code 333s excluded, representing 46 babies excluded)
Code 333 called, but vaginal birth (n=8 code 333s excluded, representing 8 babies excluded)
Multiple births (code 333 included, but second baby excluded): (n=0 code 333s excluded, 12 babies excluded)
Analysis
Number of code 333s meeting criteria (n=190, representing 190 babies)
"CARD" campus (n=107 code 333s, representing 107 babies)
"No CARD" campus (n=83 code 333s, representing 83 babies)
(b) Post-intervention
Enrollment
Number of code 333s (n=87, representing 90 babies)
"CARD" campus (n=43, representing 45 babies)
"No CARD" campus (n=44, representing 45 babies)
Number of code 333s excluded (n=10)
Number of babies excluded (n=13)
Missing maternal MRN (n=4 code 333s excluded, representing 5 babies excluded
Code 333 called, but vaginal birth (n=6 code 333s excluded, representing 6 babies excluded)
Multiple births (code 333 included, but second baby excluded) (n=0 code 333s excluded, 3 babies excluded)
Analysis
Number of code 333s meeting criteria (n=77, representing 77 babies)
"CARD" campus (n=38 code 333s, representing 38 babies)
"No CARD" campus (n=39 code 333s, representing 39 babies)

◀**Fig. 3** Study flow chart. A) Pre-intervention; B) Post-intervention. A code 333 represents an overhead call indicating an obstetrical emergency. "CARD" refers to cognitive aids with roles defined, the cognitive aid implemented at one of the two campuses. Some code 333s involve twins; we considered time to delivery of the first twin only.

teaching.[17] Nevertheless, it has been shown that didactic team training offered to interprofessional teams can in itself improve clinical care for trauma,[24] and can even decrease surgical mortality.[25] In obstetrical crises, team simulation training decreases time to delivery[26] and improves neonatal outcome in obstetrical crises.[27] Online interprofessional team training may therefore be an important component of our intervention. Future work

Table 2 Patient characteristics

	CARD campus	"No CARD" campus
Number of code 333s		
Before intervention	107	83
After intervention	38	39
Mother's age (yr)		
Before intervention	31 [27–35]	33 [28–36]
After intervention	34 [30–37]	31 [28–34]
Cases of multiple births		
Before intervention	6	1
After intervention	0	1

Data are represented as median [interquartile range].

CARD = cognitive aids with roles defined.

Code 333 = obstetrical Cesarean delivery.

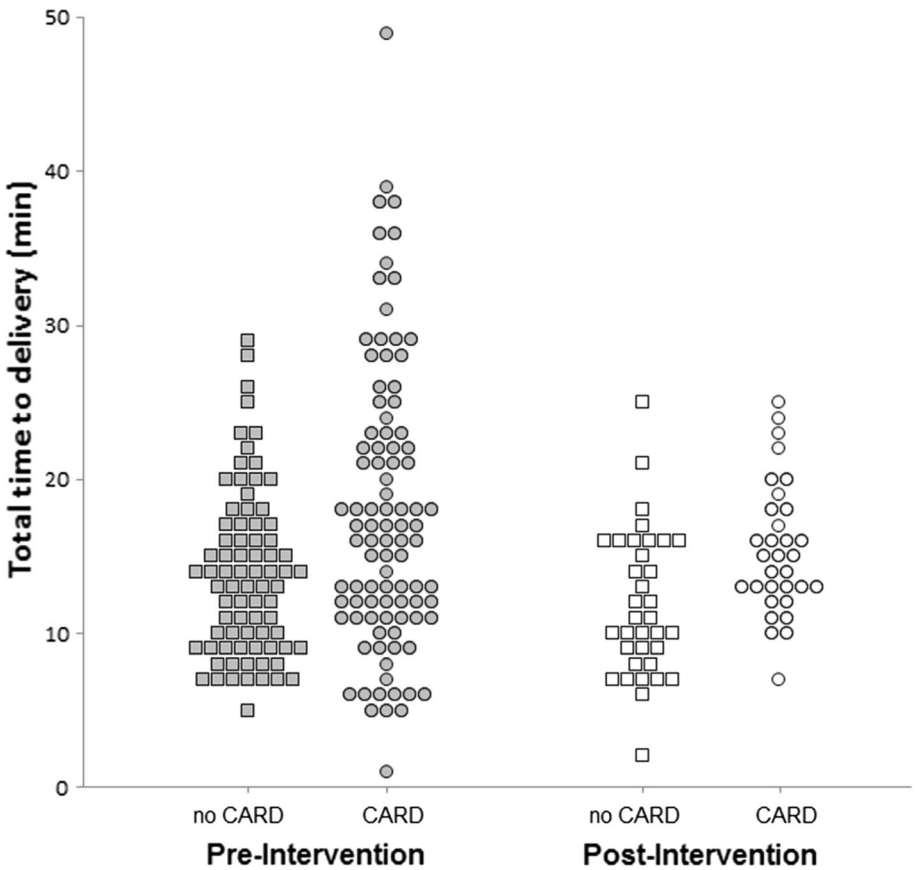


Fig. 4 Time to delivery pre-intervention and post-intervention. "CARD" refers to cognitive aids with roles defined, the cognitive aid implemented at one of the two campuses. Each point represents one Cesarean delivery.

Table 3 Time-based and clinical secondary outcome measures

	"CARD" campus			"No CARD" campus			"CARD" *vs* "No CARD"	
Time-based outcomes	Pre	Post	*P* value	Pre	Post	*P* value	*P* value Pre	*P* value Post
Time to prepare patient	18 [12–25]	15 [11–19]	0.05	11 [8–15]	9 [7–13]	0.09	< 0.001	0.001
Time to transfer patient	2 [0–3]	1 [0–3]	0.47	2 [0–3]	2 [1–4]	0.73	0.50	0.19
Time to anesthetize	16 [11–26]	12 [10–19]	0.12	9 [6–13]	7 [4–9]	0.04	< 0.001	< 0.001
Time to surgical delivery	3 [2–6]	2 [2–4]	0.20	4 [2–5]	2 [2–4]	0.02	0.17	0.59
Clinical outcomes: baby								
Apgar at 1 min	7 [4–9]	8 [1–9]	0.90	8 [5–9]	8 [4–9]	0.94	0.34	0.61
Apgar at 5 min	9 [7–9]	9 [8–9]	0.89	9 [8–9]	9 [7–9]	0.17	0.02	0.75
Arterial cord blood pH	7.19 [7.08–7.25]	7.18 [7.07–7.25]	0.85	7.17 [7.08–7.24]	7.21 [7.12–7.25]	0.19	0.36	0.76
NICU admission (%)*	26%	43%	0.08	42%	42%	0.96	0.04	0.94
Length of stay, baby (days)	3 [3–7]	3 [2–8]	0.14	3 [2–3]	2 [2–4]	0.62	< 0.001	0.17
Mortality, baby (%)	1%	3%	0.42	0%	3%	0.14	0.38	0.95
Cord acidosis (%)	36%	37%	0.92	42%	26%	0.08	0.41	0.29
Clinical outcomes: mother								
Unexpected ICU (%)	1%	3%	0.45	0%	3%	0.14	0.38	1.00
Length of stay, mother (days)	3 [2–3]	3 [2–3]	0.03	3 [2–3]	2 [2–3]	0.005	0.06	0.08
Mortality, mother (%)	0%	0%	—	0%	0%	—	—	—

Data are presented as median [interquartile range]. CARD = cognitive aids with roles defined; ICU = intensive care unit; NICU = neonatal intensive care unit. *Considers NICU admission of babies older than 36 weeks gestational age. Babies younger than this are always admitted to the NICU.

may explore the effectiveness of online team training for code 333s on a larger scale as it may be a relatively feasible and inexpensive intervention compared with other educational modalities such as simulation-based education.

We observed a numerical reduction in median time to delivery of two minutes at the "CARD" campus and three minutes at the "no CARD" campus. Though neither result was statistically significant, it is possible that this represents a clinically meaningful effect that our study was not powered to identify. Since these improvements were similar in scale, they may be the result of the eLearning module on CRM skills that was implemented at both campuses, rather than due to the CARD implementation that was done at only one campus. We can only hypothesize on this and future large studies may focus on the inexpensive and easy to implement eLearning modules for improving crisis management.

One of the strengths of the study is that it was conducted in a clinical setting compared with many studies that use a simulated environment to better control various factors. Although a clinical setting offers the highest level of authenticity to assess the impact of an intervention, it is more challenging to control for the actual use of the intervention. In highly stressful emergency situations like code 333s, healthcare professionals may not fully use the CARD system or may not use the cards as intended. Nevertheless, we used the most realistic clinical environment that provided pragmatic information on its effect in practice.

Another strength of this study is that it captured data on Kirkpatrick's level 3 and 4[28]—practice in clinical setting and patient outcome, respectively. These levels assess whether the changes brought on by an educational intervention followed by a new type of cognitive aid for multi-professional teams have yielded benefits for the institution.

A limitation of this study was its design as a comparison between one "CARD" campus and one "no CARD" campus. Our data show differences between the hospital campuses with regard to specific windows of time within a code 333 and may reflect differences in layout, setups, or patient populations at the two campuses. These differences may warrant further exploration. Differences between the layout of each campus and the logistics involved in patient transfers during code 333 may have created difficulties in measuring the effect of the intervention itself. This is especially true when comparing the specific intervals of time that make up the time to delivery, as the teams at each campus may perform certain steps faster than the other but ultimately result in a similar total time to delivery. There

may also be differences in staff practices or in the culture and teamwork practices between the two campuses that affected the outcomes we measured, but this exploration was beyond the scope of this study. There is also the possibility that other changes may have occurred at one or both campuses over the course of the study period, meaning that our results should be interpreted with caution.

The lack of observed effect in this study may not be generalizable to other implementations of the CARD system, including other methods of training clinicians to use CARD, and other clinical settings such as community hospitals where obstetrical crises are not as commonly encountered by the medical teams. The maternal and neonatal teams at our two hospital campuses are highly specialized and experienced in managing obstetrical emergencies; therefore, the CARD system may possibly have an effect if tested in another population with less experience and training in emergencies. The study may also be underpowered as we did not achieve the initial target number of code 333s. Another possibility may be that our target of four out of 20 min improvement, which was determined by consensus of a multidisciplinary team in the absence of a citeable reference, may have been too ambitious. The consensus was that it may be possible to achieve this clinically meaningful improvement with a tool (CARD) helping front-line clinicians to focus on their respective tasks immediately.

In the present study, we did not assess the effect of CARD on team performance but aimed to explore its impact at the highest level (i.e., patient outcome). In the future, audio-video recording of clinical settings using technologies such as the OR Black Box®[29] (Surgical Safety Technologies, Toronto, ON, Canada) may allow us to investigate team performance in the clinical setting and facilitate the evaluation of the CARD system in this dimension. Finally, our post-intervention sample size was lower than anticipated. This was mainly due to the decrease in the number of code 333s at our institution. We extended the data collection period to twice as long as originally planned before electing to end the study, but this limitation could have impeded our ability to detect a smaller effect size. Future work could also involve investigating interprofessional team members' satisfaction with using CARD to help clarify roles, improve communication, and decrease stress during a crisis.

In conclusion, the present study suggests that the introduction of the CARD system after eLearning at two campuses of a Canadian academic hospital did not significantly enhance time-based and clinical maternal and neonatal outcomes of emergency Cesarean deliveries. Study design may limit the generalizability of these results to other centres.

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Author contributions *Sylvain Boet* and *M. Dylan Bould* conceived and designed the study and participated in interpretation of the data and review of the manuscript for important intellectual content. *Joseph K. Burns* contributed substantially to data analysis and interpretation, and drafted the manuscript. *Glenn Posner*, *Erika Bariciak*, *Simone Crooks*, *Ann Mitchell*, and *Gregory L. Bryson* contributed substantially to the study design, commented on data interpretation, and reviewed the manuscript for important intellectual content. All authors approved the final version to be published and agreed to be accountable for all aspects of the work thereby ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Appendix: Cognitive aids with roles defined (CARD)

AA = anesthesia assistant; BU = birthing unit; NICU = neonatal intensive care unit; RT = respiratory therapist.

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