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Time and motion study to compare electronic and hybrid data collection systems during the pandemic (H1N1) 2009 influenza vaccination campaign

Susan Quach[a,*], Jemila S. Hamid[a,c], Jennifer A. Pereira[a], Christine L. Heidebrecht[a], Julie Foisy[a], Julie A. Bettinger[b], Laura Rosella[a,c], Natasha S. Crowcroft[a,c,j], Shelley L. Deeks[a,c], Sherman D. Quan[a,d], Michael Finkelstein[c,e], Maryse Guay[f], David L. Buckeridge[g], Christopher A. Sikora[h], Jeffrey C. Kwong[a,c,i], for the Public Health Agency of Canada/Canadian Institutes of Health Research Influenza Research Network (PCIRN) Vaccine Coverage Theme Group[1]

[a] *Surveillance and Epidemiology, Ontario Agency for Health Protection and Promotion, Toronto, Canada*
[b] *Vaccine Evaluation Center, University of British Columbia, Vancouver, Canada*
[c] *Dalla Lana School of Public Health, University of Toronto, Toronto, Canada*
[d] *Centre for Innovation in Complex Care, Toronto General Hospital, Toronto, Canada*
[e] *Toronto Public Health, Toronto, Canada*
[f] *Département des sciences de la santé communautaire, Université de Sherbrooke, Longueuil, Canada*
[g] *Department of Epidemiology, Biostatistics, and Occupational Health, McGill University, Montreal, Canada and Direction de santé publique de Montréal, Canada*
[h] *Department of Community Medicine, University of Alberta, Edmonton, Canada*
[i] *Institute for Clinical Evaluative Sciences, Toronto, Canada*
[j] *Laboratory Medicine and Pathobiology, University of Toronto, Toronto, Canada*

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ABSTRACT

During the pandemic (H1N1) 2009 vaccination campaign, vaccine providers collected immunization data using hybrid (paper-based and electronic methods) and electronic data systems. We measured staff time in seconds spent on data collection tasks to compare system efficiencies. The sample consisted of 38 organizations across nine Canadian provinces/territories. The total mean data collection times per client were 104 s (electronic system), 143 s (hybrid system with electronic registration) and 172 s (hybrid system with paper registration). Electronic registration and record keeping were faster than paper-based methods; these findings should be used to improve data collection for future influenza seasons.

1. Introduction

The pandemic (H1N1) 2009 vaccination campaign was the largest mass immunization program in Canadian history. Vaccine providers were responsible for collecting immunization information to allow monitoring of vaccine coverage rates. These data served many purposes for public health planning and research [1]; consequently, significant investments were made in many jurisdictions to capture immunization coverage data and retain key client information in registries or other electronic databases.

Various data collection systems were utilized across Canada, of which many were newly adopted or modified based on the data needs, reporting requirements and available resources of respective jurisdictions. Given the variation in data collection systems and the need for timely immunization data during the pandemic, we conducted a comparison of system efficiencies to inform immunization program planners. Time spent by clinic staff to collect and record immunization data is one indicator of efficiency. Previous studies of clinic workflow and processes have relied upon work sampling techniques and self-reporting surveys [2]. However, continuous observation time and motion measurement, in which an observer follows a subject and records the time spent on each activity in a standardized format, is considered more precise when tasks are clearly defined and structured [3]. Employing this type of methodology in an immunization setting provides valuable information with which to optimize vaccine data collection approaches.

This is the first large-scale national study using time and motion methodology to examine the amount of time spent by immunization staff on the collection of pandemic immunization data to compare efficiencies between data collection systems. We also assessed the determinants of data collection efficiency and studied

Abbreviations: ECR, electronic client registration; PCR, paper client registration; E, electronic; P, paper.

* Corresponding author at: 480 University Ave., Suite 300, Toronto, ON M5G 1V2, Canada. Tel.: +1 647 260 7420.
E-mail address: susan.quach@oahpp.ca (S. Quach).

[1] See Appendix A for a list of members.

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Table 1
Description and example of tasks using paper or electronic methods.

Task	Description of task	Example method: paper (P)	Example method: electronic (E)
Data collection tasks			
Client registration	Time required to collect and record client's demographic information (e.g., name, sex, date of birth, postal code, health card number)	Clerk fills out demographic information for client	Swipe card or pre-populated database used to obtain demographic information
Medical history collection	Time required to collect and record client's risk status, chronic conditions, allergies, contraindications and previous seasonal influenza vaccination status	Nurse/clerk records medical information on consent form	Clerk clicks a series of boxes to record medical information
Vaccine record keeping	Time spent to record information on vaccine administration (e.g., vaccine, dosage, dose number, lot number, vaccinator's name, site of vaccination)	Nurse writes lot numbers on form or checks off details if form is pre-filled	Nurse clicks screen with pre-populated vaccine lot information
Preparation of vaccine proof	Time to prepare a record of vaccination given to the client	Nurse fills out card for client or provides pre-printed vaccine proof or carbonless copy	Nurse prints vaccine proof
Post-vaccination data entry	Time to enter data for one record or consent form into a hybrid system	Data entry clerk enters information from consent form into database	Not applicable – done at the point of vaccination
Non-data collection tasks			
Medical history review	Time spent to review client's medical history, provide client education and record additional information if missing		
Time required with immunization nurse	Time spent with client at the immunization station (collect/review medical history, provide vaccination, client education, record keeping, preparation of vaccine proof, if applicable)		

the underlying heterogeneity among the different tasks and systems.

2. Methods

2.1. Study setting and population

We conducted a pan-Canadian prospective observational study consisting of passive observation, time and motion measurements, and a user perceptions questionnaire. All public health jurisdictions and a convenience sample of acute-care hospitals were invited by email to participate. For each organization, we arranged site visits on three different dates at different periods of the day to capture a range of client throughput. These visits were conducted in the same clinic location or in different clinics with similar data collection procedures. At each of the three site visits, we aimed to collect 20 observations for each data collection task in an unobtrusive manner. When it was not feasible to coordinate the visits over three days, we collected the same number of observations over two days. Details of the protocol for the study have been described previously [4]. This paper will focus only on the time and motion component; results of the other components will be described separately.

2.2. Time and motion measurements

A trained observer timed the completion of each task by watching staff members perform their respective duties [4]. Before measurements were taken, the observer defined for each task start and end times, which were based on both visual and verbal cues. For example, the "start time" for client registration may consist of the client handing their health card to the registration clerk, while the "end time" may consist of the clerk completing all registration-related data fields. The observer used a tablet computer and recorded task times in an electronic data collection form (which included a time-stamp function for timing the tasks). When the use of electronic devices was not feasible at a study site, the observer used a stopwatch and paper forms, and subsequently entered the observations into a spreadsheet.

2.3. Main outcome measure and variables

The main outcome of the study was the time in seconds spent by staff to complete specific data collection tasks. Five different tasks related to immunization data collection were assessed: (1) client registration; (2) medical history collection; (3) vaccine record keeping (e.g., lot number, date of administration); (4) preparation of vaccine proof; and (5) post-vaccination data entry (definitions for these tasks are provided in Table 1).

A data collection *system* in its entirety was classified as being either electronic or hybrid. However, each data collection *task* within a system could be classified as electronic or paper-based. For electronic systems, all data collection-related tasks used electronic methods, whereas hybrid systems included both electronic and paper-based methods. When we analyzed specific tasks, we compared times for electronic and paper-based methods. Only total times were compared between data collection systems. No paper-only systems were observed at any clinics.

Data on additional variables at clinic and task levels were also collected. Clinic-level factors included visit date, site, urban/rural location, client flow (CF), clinic population, number of vaccinators and number of clinic hours. Client flow was defined as the number of clients vaccinated by a nurse within an hour and was dichotomized as being high ($CF \geq 10$; 10 or more clients vaccinated per nurse per hour) or low ($CF < 10$; fewer than 10 clients vaccinated per nurse per hour). As we anticipated that the first week of the vaccination campaign would operate differently than subsequent weeks, visit dates were dichotomized according to when the campaign started within the respective jurisdictions. Clinics were classified as urban or rural based on the postal code definition used by Canada Post [5]. Clinic population at the time of the visit was classified as being general population or priority groups [6]. The sole task-level factor was the number of data elements collected and this was based on the number of variables collected for a task.

2.4. Statistical analysis

We performed all analyses using Stata 10 (Statacorp, College Station, TX) [7]. We calculated descriptive statistics (mean, stan-

Table 2
Characteristics of clinics visited by data collection system (electronic vs. hybrid).

		Number of clinics visited (%) (N = 79)		Number of tasks observed (N = 11348)					
				Hybrid systems with paper client registration (%) (N = 5827)		Hybrid systems with electronic client registration (%) (N = 3326)		Electronic systems (%) (N = 2195)	
Province	Newfoundland	6	(7.6)	0	(0)	810	(24.4)	0	(0)
	Nova Scotia	15	(19.0)	1523	(26.1)	630	(18.9)	0	(0)
	Quebec	6	(7.6)	0	(0)	1600	(48.1)	0	(0)
	Ontario	15	(19.0)	0	(0)	286	(8.6)	2195	(100)
	Manitoba	14	(17.7)	1575	(27.0)	0	(0)	0	(0)
	Saskatchewan	8	(10.1)	1416	(24.3)	0	(0)	0	(0)
	Alberta	8	(10.1)	698	(12.0)	0	(0)	0	(0)
	British Columbia	5	(6.3)	512	(8.8)	0	(0)	0	(0)
	Nunavut	2	(2.5)	103	(1.8)	0	(0)	0	(0)
Organization type	Public health center	74	(93.7)	5527	(94.9)	3189	(95.9)	2195	(100)
	Hospital	5	(6.3)	300	(5.2)	137	(4.1)	0	(0)
Clinic setting	Conference centre	5	(6.3)	570	(9.8)	0	(0)	193	(8.8)
	School	8	(10.1)	883	(15.2)	531	(16.0)	307	(14.0)
	Church	5	(6.3)	508	(8.7)	0	(0)	0	(0)
	Health centre	8	(10.1)	548	(9.4)	317	(9.5)	0	(0)
	Mall	11	(13.9)	721	(12.4)	259	(7.8)	585	(26.7)
	Community centre	22	(27.8)	1620	(27.8)	1052	(31.6)	225	(10.3)
	Auditorium	15	(19.0)	672	(11.5)	1167	(35.1)	386	(17.6)
	Cafeteria	2	(2.5)	262	(4.5)	0	(0)	0	(0)
	Municipality centre	3	(3.8)	43	(0.7)	0	(0)	499	(22.7)
Population	General population	37	(46.8)	2572	(44.1)	2074	(62.4)	1466	(66.8)
	Priority	33	(41.8)	2665	(45.7)	1115	(33.5)	728	(33.2)
	Health care personnel	5	(6.3)	300	(5.2)	137	(4.1)	0	(0)
	Children	4	(5.1)	290	(5.0)	0	(0)	0	(0)
Week of vaccination campaign	1st week	20	(25.3)	928	(15.9)	810	(24.4)	240	(10.9)
	>1st week	59	(74.7)	4899	(84.1)	2516	(75.7)	1955	(89.1)
Clinic location	Rural	27	(34.2)	2465	(42.3)	263	(7.9)	168	(7.7)
	Urban	52	(65.8)	3362	(57.7)	3063	(92.1)	2027	(92.4)

dard deviation, median, 95% confidence intervals, and 25th and 75th percentiles) for each task by data collection method (paper or electronic). The mean times for each data collection task (client registration, medical history collection, vaccine record keeping, preparation of vaccine proof and post-vaccination data entry) were combined to obtain a total mean time for the entire data collection process for each system. Significance testing to assess the difference between the total mean times for each system was not performed because the variance could not be estimated without information specifying which observations were based on the same client. Also, observations were collected on the same nurse and this information was not consistently collected. When we ran a crude analysis comparing mean times for electronic and paper methods on a subset of the data which assumed correlation of observations from the same nurse, the results of mean times were similar and we therefore assumed the observations were independent in the stratified analysis to avoid eliminating a large proportion of our sample where this information was missing.

When comparing data collection methods for each task, we recognized that the number of data elements collected during a task was likely to influence the data collection time, and that the number of elements collected may have been associated with the data collection method. Therefore, we conducted a stratified analysis to compare data collection times between paper and electronic methods where approximately equal numbers of data elements were collected (within a range of ±5 elements) for a given task. We also conducted further stratified analyses to control for other extraneous factors (visit date, site, urban/rural location, client flow (CF), clinic population). For example, if the number of data elements collected for client registration using an electronic method was 13, we only compared those data with paper methods that collected between 8 and 18 data elements. Comparing electronic and paper-based methods based on exactly equal number of data elements would have resulted in no observations or very few observations in some strata. In total, we excluded 32% (n = 1637/5192) of observations (405 of 1643 client registration observations, 471 of 924 medical history observations and 761 of 2607 vaccine record keeping observations) due to the lack of an appropriate comparison based on the number of data elements collected. Comparisons between paper and electronic methods of data collection were made within each stratum using the Wilcoxon Rank Sum test and forest plots with 95% confidence intervals around the mean. Other task-level factors such as grouped observations (i.e., a task was conducted on multiple individuals at once or in a continuous sequence) and number of vaccine doses given were not examined through stratified analysis due to insufficient sample size (<2% of observation had these attributes). All tests were two-tailed and we used $p < 0.05$ as the level of statistical significance.

2.5. Ethics

We obtained ethics approval from the University of Toronto's Health Sciences Research Ethics Board. Additionally, approval from other regional or university ethics boards was obtained when required.

3. Results

Between 27 October and 17 December 2009, 11,348 observations were collected from 79 immunization clinics representing 38 organizations across nine provinces and territories. Of 165 organizations contacted, 23% (n = 38) participated in the study. Nine organizations (23.7%) used a fully electronic system, seven (18.4%) used a hybrid system with electronic client registration (ECR), and

22 (57.9%) used a hybrid system with paper client registration (PCR). We collected observations from more than 427 staff members including nurses, volunteers, and clerks. No difference in the median number of years of immunization experience was observed between nurses using electronic or hybrid systems. Characteristics of clinics visited by type of data collection system are presented in Table 2. A fully electronic system was only observed at clinics in a single province. Most site visits took place at public health clinics (93.7%), in urban settings (65.8%), and after the first week of the vaccine campaign (74.7%).

3.1. *Time required by data collection task*

The time required for each data collection task varied greatly by organization and by the type of data collection system (data not shown). The overall mean time in seconds for client registration was 49.5 s, with electronic methods requiring less time than paper methods (46.8 s vs. 54.5 s) (Table 3). Similarly, vaccine record keeping required less time using electronic methods than paper methods (9.4 s vs. 30.1 s). However, time to collect and review medical history was longer with the electronic method (48.0 s vs. 35.0 s). When vaccine proof was provided using a paper method, the mean time was 13.4 s; this did not require any time using an electronic system because it was printed off automatically. Post-vaccination data entry of consent forms required a mean of 39.8 s per record using a hybrid system. No significant differences between methods for the mean time spent with an immunization nurse were observed (E = 166.1 s; 95% CI, 156.6–175.6, P = 160.7 s; 95% CI, 154.7–166.8).

3.2. *Time required by data collection system*

The total mean time per client for all combined data collection tasks was 104.4 s using electronic systems, 142.7 s for hybrid systems with ECR, and 171.8 s for hybrid systems with PCR. The post-vaccination data entry times were significantly longer for hybrid systems with ECR compared to PCR (45.3 s vs. 33.3 s, $p < 0.001$). With electronic systems, no time was required for post-vaccination data entry because data were already entered directly into the system. For hybrid systems, total mean time for all data collection tasks varied by organization. For example, organizations entering data into a provincial registry by a batch data entry process required a total mean time of 45 s per client, whereas organizations using a standalone Microsoft Excel line listing for data entry required 257 s per client. Data entry times varied by the amount of information entered, type of database (standalone or pre-populated with demographic client data) and system capabilities (data not shown).

3.3. *Stratified analysis*

Since organizations collected varying amounts of client-level information, we examined the number of data elements collected and the associated times by data collection task. Data collection times for client registration, medical history collection and vaccine record keeping were approximately twice as long when the number of data elements collected was greater than 8 ($p < 0.0001$).

When controlling for the number of data elements collected, client registration using an electronic method required less time than paper (Fig. 1); the difference was greater after the first week of the vaccine campaign (43.5 s; 95% CI, 41.6–45.4 s vs. 67.9 s; 95% CI, 64.0–71.9). When an electronic method was used, high client flow was associated with significantly shorter client registration times than low client flow (high client flow: 39.2 s; 95% CI, 36.8–41.6 vs. low client flow: 52.8 s; 95% CI, 48.4–57.2), but there was no difference when using a paper method. There were no differences in client registration times between clinic population groups (general

Table 3
Median and mean time (s), 95% CI, 25 and 75 percentiles for each task by data collection method.

Task name	Data collection method													
	Overall				Electronic (E)					Paper (P)				
	n	Mean	95% CI	Median	*n*	Mean	95% CI	Median	25, 75%	*n*	Mean	95% CI	Median	25, 75%
Client registration	1643	49.5	(48.1,50.9)	44	423	49.6	(46.8, 52.3)	47	29, 65	586	54.5	(51.9, 57.1)	49	33, 69
Client registration (*hybrid system)					634	44.9	(42.9, 46.9)	38	28, 55					
Medical history collection	924	33.6	(31.8,35.4)	26	441	42.8	(39.7, 45.9)	32	22.5, 52	483	25.1	(23.4, 26.9)	22	3, 69
Review medical history	1772	37.9	(36.3,39.5)	28	397	48.0	(44.4, 51.6)	38	22, 65	1375	35.0	(33.2, 36.8)	25	2, 135
Vaccine record keeping	2607	27.2	(26.5,27.9)	23	373	9.4	(8.5, 10.3)	7	5,12	2234	30.1	(29.4, 30.9)	25.5	4, 74
Preparation of vaccine proof	928	13.4	(12.6,14.2)	10	[a]	0		0		928	13.4	(12.7, 14.2)	10	3, 48
[b]Time required with immunization nurse	1390	161.9	(156.7,167.1)	138	312	166.1	(156.6, 175.6)	147.5	111, 200	1078	160.7	(154.7, 166.8)	134	45, 414
Post-vaccination data entry (hybrid system)	540	39.8	(37.1,42.5)	29	540	39.8	(37.1, 42.5)	29	21, 50	0	0		0	
Client registration and collect medical history	409	32.1	(27.4,36.8)	12	149	71	(60.9, 81.1)	34	22, 111	260	9.8	(8.7, 10.9)	7	5, 11.75
Collect and review medical history	167	105.1	(97.6,112.6)	95	60	138.9	(125.5, 152.3)	126	101, 168.5	107	86.2	(74.7, 97.8)	68	48, 109
Review medical history and record keeping	196	72.0	(70.0,74.0)	60.5	85	69.7	(62.6, 87.3)	65		111	74.9	(61.8, 77.6)	57	44, 80
Collect medical history and record keeping	221	47.7	(43.1,52.4)	40						221	47.7	(43.0, 52.4)	40	31, 51.5

[a] Preparation of vaccine proof time was equal to 0 s in the electronic system because this was printed automatically.
Client registration (*hybrid system) refers to those observations based on electronic client registration (ECR).
[b] Time required with immunization nurse consists of the total time that a client spends with the immunization nurse which also includes immunization related tasks (i.e., administration of vaccine, client education etc.).

Table 4
Stratified analysis[a] for client registration, medical history collection, vaccine record keeping.

Subgroup	Median time in seconds (number of observations)					
	Client registration	z score p value	Vaccine record keeping	z score p value	Medical history collection	z score p value
Urban	$E=38$ (703)	$z=4.6$	$E=7$ (353)	$z=22.7$	$E=36$ (361)	$z=-1.1$
	$P=47$ (77)	$p<0.0001$	$P=24$ (927)	$p<0.0001$	$P=32$ (72)	$p=0.2691$
Rural	$E=60$ (20)	$z=1.3$	$E=6$ (20)	$z=7.5$	$E=83$ (20)	
	$P=67$ (224)	$p=0.2094$	$P=37$ (483)	$p<0.0001$		
General population	$E=37$ (586)	$z=9.7$	$E=8$ (258)	$z=20.4$	$E=39$ (244)	
	$P=61$ (164)	$p<0.0001$	$P=26$ (768)	$p<0.0001$		
Priority groups	$E=46$ (137)	$z=6.6$	$E=5$ (115)	$z=15.4$	$E=34$ (137)	$z=-0.7$
	$P=68$ (137)	$p<0.0001$	$P=32$ (578)	$p<0.0001$	$P=32$ (73)	$p=0.4864$
Low client flow (CF)	$E=45$ (174)	$z=8.2$	$E=12$(115)	$z=14.5$	$E=39$ (57)	
	$P=67$ (203)	$p<0.0001$	$P=33$ (797)	$p<0.0001$		
High client flow (CF)	$E=34$ (344)	$z=7.3$	$E=5$ (118)	$z=14.9$	$E=28$ (181)	$z=1.7$
	$P=51$ (98)	$p<0.0001$	$P=23$ (503)	$p<0.0001$	$P=39$ (16)	$p=0.0967$
1st week of vaccination campaign	$E=54$ (60)	$z=3.3$	$E=4$ (60)	$z=11.7$	$E=26.5$ (60)	
	$P=73$ (28)	$p=0.001$	$P=26$ (277)	$p<0.0001$		
After 1st week of vaccination campaign	$E=37$ (663)	$z=13.0$	$E=8$ (313)	$z=23.4$	$E=39$ (321)	$z=-2.4$
	$P=63$ (273)	$p<0.0001$	$P=29$ (1133)	$p<0.0001$	$P=32$ (72)	$p=0.015$

[a] Stratified by the number of data elements collected and additional factors. Only observations where the number of data elements collected were similar (±5 data elements) between paper and electronic methods were compared.
"E" represents electronic method. "P" represents paper method.

vs. priority). Client registration times were faster in urban locations compared to rural locations for electronic methods but not paper methods. We also found similar results when we conducted non-parametric tests between subgroups to assess statistical significance (Table 4).

Clinics using an electronic method ($n=13$) collected a total of 29 data elements to assess medical history, whereas only 14 clinics collected a similar amount of information using a paper method. Consequently, post-stratified sample sizes were small and some forest plots had no observations for certain subgroups. After comparing clinics that collected the same level of information and stratifying by other influential time covariates, there were no differences between electronic or paper times for medical history collection.

Vaccine record keeping required significantly less time using an electronic method compared to paper across all factors, taking less than 20 s per electronic record compared to at least 25 s with paper methods (Fig. 1). Mean times for electronic approaches were shorter for the first week compared to the subsequent weeks (4.6 s; 95% CI, 3.7–5.4 s vs. 10.3 s; 95% CI, 9.3–11.4), while no difference was observed for paper methods. High client flow was associated with faster record keeping time for both electronic and paper. There were no differences between clinic populations using electronic methods, whereas vaccinating general population groups was faster than vaccinating priority groups for paper. Vaccine record keeping was faster in urban clinics than in rural clinics using paper methods, whereas the reverse was observed for electronic approaches. Again, similar results were achieved when non-parametric tests were used to test sub-group comparisons (Table 4).

4. Discussion

This is the first study using a continuous observation time and motion design to examine the efficiency with which staff collected immunization data during the pandemic (H1N1) 2009 influenza campaign. Data collection approaches varied across Canada, with the majority of clinics observed using hybrid systems. Compared to hybrid systems, data collection took less time using electronic systems on average because a number of labour intensive tasks were automated or eliminated. For instance, electronic client registration and vaccine record keeping were significantly faster than paper methods. Also, preparation of a vaccine proof was rapid using an electronic system because this task was automated within the software program. We also identified other critical factors that influenced data collection times, such as the number of data elements collected, population groups served, rate of client flow, and the week the clinic occurred over the course of the pandemic. These are important factors to consider when comparing task times across multiple settings.

We demonstrated that vaccine record keeping and client registration were streamlined by using electronic systems at the point of care, similar to a previous study that examined electronic systems for mass vaccination clinics [8]. For example, swipe card readers and pre-populated registries were used for client registration in some clinics, and this was faster than manually copying information from health cards. Record keeping was also faster using electronic methods because vaccine lot numbers were pre-entered and nurses were only required to check boxes and select fields from drop-down menus. At clinics using hybrid systems, considerable resources were spent processing forms (i.e., counting and sorting) for data reporting. Billitier *et al.* found that seven person-hours were required to sort and alphabetize the paper forms for 500 influenza vaccinations [8].

Among hybrid systems, we observed a number of approaches that may reduce staff workload. Some clinics used carbonless copies or generic slips as vaccine proof for the client, which required no additional staff time. Pre-filled forms with common information such as lot numbers, dates, and clinic names/locations, also reduced manual work required of clinic staff during the immunization process, although this information needed to be filled out prior to the immunization process. Having clients self-register could be appropriate when staff resources are limited and clients are knowledgeable about the vaccine and their medical history (such as in a hospital setting). However, this process could be problematic for post-vaccination data entry if the information is missing or illegible.

Interestingly, high client flow was associated with shorter data collection times in the electronic system. Long client wait-times may motivate staff to perform their duties more quickly than otherwise or may prompt staff to eliminate non-essential tasks. Electronic methods were faster for client registration and vaccine record keeping after the first week of the vaccine campaign indicating that staff may need time to adjust to the data collection system and/or indicate necessary time to address issues in the system. We expected that task times would differ by population group because we hypothesized that individuals in priority vaccination

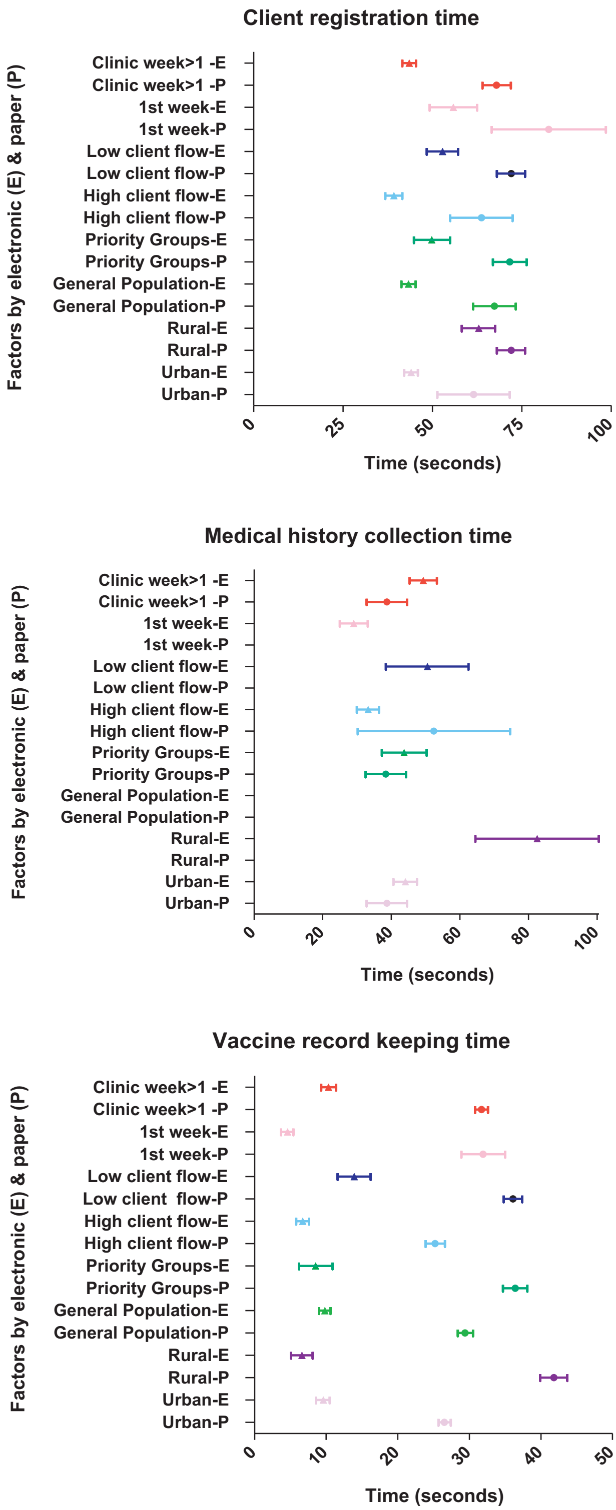

Fig. 1. Stratified analysis by two factors for client registration, medical history collection, vaccine record keeping times. All comparisons were stratified by the number of data elements collected and an additional factor, as indicated on the plot. Only observations where the number of data elements collected was approximately equal (±5 data elements) between paper and electronic methods were compared. "E" represents an electronic method was used for the data collection task. "P" represents a paper method was used for the data collection task. "CF" represents client flow. "Clinic week > 1" represents clinic visits that occurred after the first week of the vaccination campaign. "1st week" represents clinic visits that occurred within the first week of the vaccination campaign. Triangles represent the mean times with 95% confidence intervals for tasks using an electronic method. Circles represent the mean times with 95% confidence intervals for tasks using a paper method.

groups would require more time for medical history collection or would have more questions for staff, thereby prolonging data collection tasks. However, this difference was not evident in this study, which may relate to how we defined the population groups. Observations were classified by population group at the level of the clinic rather than the client. It would be informative for future research to collect client-level information such as age, sex, and underlying health status to examine how this might have an impact on clinic times.

Few studies have examined the amount of time spent by staff on administrative work related to vaccinations. We showed that the total mean time spent on data collection per client ranged from 117 to 172 s, depending on the type of system. In a study conducted in children under two years of age, the largest proportion of vaccine-related time was attributable to paperwork, ranging from 114 to 270 s depending on the number of injections given [9]. These results are not wholly comparable to our study since the populations in this study and ours were different and it is unclear which tasks were included in the assessment. In another study, record keeping for paediatric influenza vaccination visits took a median of 60 s per client [10]. These results also differ from our vaccine record keeping time (median time = 23 s per client) and this could be a result of the number and type of data elements collected, as well as differences in the population under study, as our study was not limited to the paediatric population. Regardless, our findings complement other studies by highlighting the amount of time spent by staff to collect immunization data and identifying the most efficient approach during mass vaccination clinics.

Several methodological challenges associated with measuring task times using time and motion methodology should be noted. The study would have benefited from piloting the methods in a range of settings using different data collection approaches. Although we tested the methodology at two similar clinics using a hybrid system, due to the urgency of the vaccination campaign, we were unable to observe the full range of data collection approaches during the pilot phase. Therefore, there may have been some variability in task classification and start and end definitions across data collection approaches. For example, paper-based tasks depended on verbal and behavioural cues that were often inconsistent, whereas electronic cues were more objective as they were based on screen displays. Further, it was difficult to quantify the time spent on one record for some tasks completed in a continuous sequence. For example, we did not account for the time spent pre-filling vaccine lot numbers into computer systems or pre-stamping vaccine lot numbers on consent forms (for hybrid systems). Although these tasks should be included as part of vaccine record keeping, we do not expect these times to be sufficiently long per record to change the overall results of this study. There are several other time components which were not directly measured as part of this study and should be considered when evaluating resource utilization for different systems. For example, considerable time was spent counting and sorting consent forms in the hybrid systems and this was not included in the analysis. Such processing times would increase total data collection times for hybrid systems and would make electronic systems appear even more time efficient, as electronic systems did not use paper consent forms. Other system-specific tasks such as setting up technical equipment, photocopying, staff training, data cleaning, and analysis were not included but can be explored in future studies.

As observed in other time and motion studies [3,9–11], multitasking was a common impediment to precise timing, especially for hybrid systems. The electronic system followed a pre-defined order where it was impossible to perform several data collection tasks simultaneously. In contrast, nurses using a hybrid system could collect and review medical history simultaneously which was more efficient but difficult to measure separately. It was also common for nurses to prepare vaccines or engage in clinical activities such as patient education while performing data collection tasks, which explains some of the variability across observation times.

Our stratified analysis was limited because we could not examine all of the interactions between factors in a single analysis. Since some factors were related to each other, their effects may not be as apparent once they are analyzed in multivariate hierarchal models. Other unmeasured confounders may impact the task times, such as nurse characteristics (e.g., years of immunization experience, years of experience with immunization information system, type of nurse) or client characteristics (e.g., age, chronic medical condition) and we could not adjust for these factors. However, it would be difficult to adjust for multiple potentially confounding factors in a stratification analysis as there would be too many strata with low sample size in each stratum.

Consistently recording nurse and client identifiers for each observation would have provided a unit of analysis to allow hierarchical/multilevel models and allowed us to assess the statistical significance of differences between data collection systems in total times. The lack of individual-level client data prevented us from assessing the significance of such differences, as measurements from different tasks were not independent and this information was not captured during the data collection process.

As our study results are based on a low participation rate (23%), and are mostly limited to public health mass vaccination clinics, they may not be representative, and may not be generalizable to non-public health settings. Additionally, the clinic manager scheduled the site visits and often chose staff members to be observed. This may have also affected the generalizability of the results, as some managers requested that we: (i) visit later in the campaign when clinics were less active and staff had adjusted to the new data system; and (ii) observe more experienced staff members. Further, since participants knew that they were being observed, we may have observed a Hawthorne effect, with participants performing faster than normal.

Despite the limitations described, the findings from this study can contribute to understanding a component of clinic efficiency, specifically highlighting areas for improvement to streamline data collection processes. We observed a range of data collection approaches used across both urban and rural settings in 9 (of 13) provinces and territories in Canada. Our study encompassed the majority of the vaccine delivery and administration period, including clinics operating at maximum capacity.

Identifying the most efficient approaches for data collection and sharing these lessons learned will provide valuable information for future immunization planning. Overall, users of electronic data collection systems required less time than users of hybrid systems to complete data collection-related tasks. Specifically, client registration and vaccine record keeping were performed significantly faster using an electronic method compared to paper-based methods. These tasks contributed the most to the reduction in overall data collection times, offered the greatest capacity to collect a wide range of data elements, and improved the overall efficiency of the data collection system. Electronic data collection systems utilized innovative features such as swipe-card readers and relied on pre-populated data fields to eliminate or minimize the amount of labour-intensive, repetitive and time-consuming activities. Immunization program planners can use this information to assess their current systems and determine whether modifications would optimize clinic workflow for future influenza seasons. These results provide evidence that integrating electronic components into data collection immunization processes can contribute to reducing staff time on administrative duties. Further, electronic data collection systems can offer the ability for data to be analyzed and applied more rapidly for decision making and timely assessment of vaccine coverage, effectiveness and safety, all of which are essential in optimizing the response to a pandemic.

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Appendix A.

PCIRN Vaccine Coverage Theme Group members are: David Allison, Julie Bettinger, Nicole Boulianne, Stephanie Brien, David Buckeridge, Larry Chambers, Jemila Hamid, Natasha Crowcroft, Shelley Deeks, Michael Finkelstein, Julie Foisy, Maryse Guay, Effie Gournis, Christine Heidebrecht, Donna Kalailieff, Faron Kolbe, Jeff Kwong, Allison McGeer, Jane Nassif, Jennifer Pereira, Susan Quach, Sherman Quan, Beate Sander, Chris Sikora, and Don Willison.

References

[1] Writing team for the Public Health Agency of Canada/Canadian Institutes of Health Research Influenza Research Network Vaccine Coverage Theme G. Why collect individual-level vaccination data? CMAJ 2009;182(3):273–5.

[2] Poissant L, Pereira J, Tamblyn R, Kawasumi Y. The impact of electronic health records on time efficiency of physicians and nurses: a systematic review. JAMIA 2005;12(5):505–16.

[3] Finkler SA, Knickman JR, Hendrickson G, Lipkin M, Thompson WG. A comparison of work-sampling and time-and-motion techniques for studies in health services research. Health Serv Res 1993;28(5):577–97.

[4] Pereira JA, Quach S, Heidebrecht CL, Foisy J, Quan S, Finkelstein MS, et al. Pan-Canadian assessment of pandemic immunization data collection: study methodology. BMC Medical Research Methodology 2010;10(51).

[5] du Plessis V, Beshiri R, Bollman RD, Clemenson H. Definitions of "Rural"; 2002, http://www.statcan.gc.ca/pub/21-601-m/2002061/4224867-eng.pdf.

[6] Public Health Agency of Canada. Pandemic vaccine prioritization framework: 4.0 considerations in applying the pandemic vaccine prioritization framework; 2009.

[7] StataCorp LP. Stata/IC 10.0 for Windows. In. 10.0 ed. College Station; 2007.

[8] Billittier AJ, Lupiani P, Masterson G, Masterson T, Zak C. Electronic patient registration and tracking at mass vaccination clinics: a clinical study. Journal of Public Health Management Practice 2003;9(5):400–10.

[9] Pellissier JM, Coplan PM, Jackson LA, May JE. The effect of additional shots on the vaccine administration process: results of a time-motion study in 2 settings. AJMC 2000;6(9):1038–44.

[10] Szilagyi PG, Iwane M, Humiston S, Schaffer S, McInerny T, Shone L, et al. Time spent by primary care practices on pediatric influenza vaccination visits: implications for universal influenza vaccination. Arch Pediatr Adolesc Med 2003;157(2):191–5.

[11] Grossman MD, Schwab CW, Chu-Rodgers S, Kestner M. Time and motion: a study of trauma surgeons' work at the bedside during the first 24 hours of blunt trauma care. Journal of Trauma – Injury Infection & Critical Care 1999;46(5):757–64.