Vaccine storage and handling

Knowledge and practice in primary care physicians' offices

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OBJECTIVE To assess the knowledge and practice of vaccine storage and handling in primary care physicians' offices.

DESIGN A cross-sectional study was conducted from August to December 1992. Staff responsible for vaccine storage were interviewed about their knowledge and practices of vaccine handling and storage. Refrigerators were inspected to document refrigerator temperature and vaccine storage conditions.

SETTING General and pediatric practices in 12 regions of Ontario.

PARTICIPANTS Practices outside metropolitan Toronto were selected by choosing every 10th physician who ordered vaccine from the local health department in 1992. Practices chosen in metropolitan Toronto were a random selection of physicians affiliated with a Toronto teaching hospital. Eighteen pediatric and 138 general practices were approached to participate; 12 pediatric and 123 general practices participated in the study. The overall response rate was 86.5%.

MAIN OUTCOME MEASURES Survey responses and temperature and storage conditions of refrigerators upon inspection.

RESULTS Fewer than seven (6%) practices answered all questions related to vaccine storage and handling correctly, and only 11 (10%) refrigerators had thermometers. One-third of refrigerators had temperatures outside the recommended range of 2°C to 8°C. Older refrigerators were more likely to have inappropriate temperatures than newer ones.

CONCLUSIONS Knowledge and practice of vaccine storage and handling are often inadequate in primary care physicians' offices.

OBJECTIF Évaluer les connaissances et les habitudes concernant la manipulation et l'entreposage des vaccins dans les cabinets des médecins de première ligne.

CONCEPTION Étude transversale menée de août à décembre 1992. Le personnel responsable de l'entreposage des vaccins a participé à une entrevue portant sur leurs connaissances et leurs habitudes de manipulation et d'entreposage des vaccins. Les réfrigérateurs ont fait l'objet d'une inspection pour documenter la température intérieure et les conditions d'entreposage des vaccins.

CONTEXTE Les pratiques générales et pédiatriques de 12 régions de l'Ontario.

PATIENTS À l'extérieur de Toronto, les pratiques ont été sélectionnées en choisissant un médecin sur 10 qui avait commandé des vaccins au département de santé communautaire en 1992. Pour la région métropolitaine de Toronto, le choix s'est porté sur une sélection randomisée de médecins affiliés à un hôpital d'enseignement de Toronto. Dix-huit pratiques pédiatriques et 138 pratiques générales furent appelées à participer; 12 pratiques pédiatriques et 123 pratiques générales ont accepté de participer à l'étude. Le taux global de réponse fut de 86,5%.

PRINCIPALES MESURES DES RÉSULTATS Analyse des réponses à l'enquête et état des réfrigérateurs lors de l'inspection (conditions de température et d'entreposage).

RÉSULTATS Moins de 6% des pratiques ont répondu correctement à toutes les questions concernant la manipulation et l'entreposage des vaccins et seulement 11 réfrigérateurs (10%) étaient équipés d'un thermomètre. Le tiers des réfrigérateurs avaient des températures en dehors de la zone recommandée de 2° à 8° C. Les vieux réfrigérateurs étaient plus exposés à un dérèglement de la température que les modèles plus récents.

CONCLUSIONS Les connaissances et les habitudes de manipulation et d'entreposage des vaccins sont souvent inadéquates dans les cabinets des médecins de première ligne.

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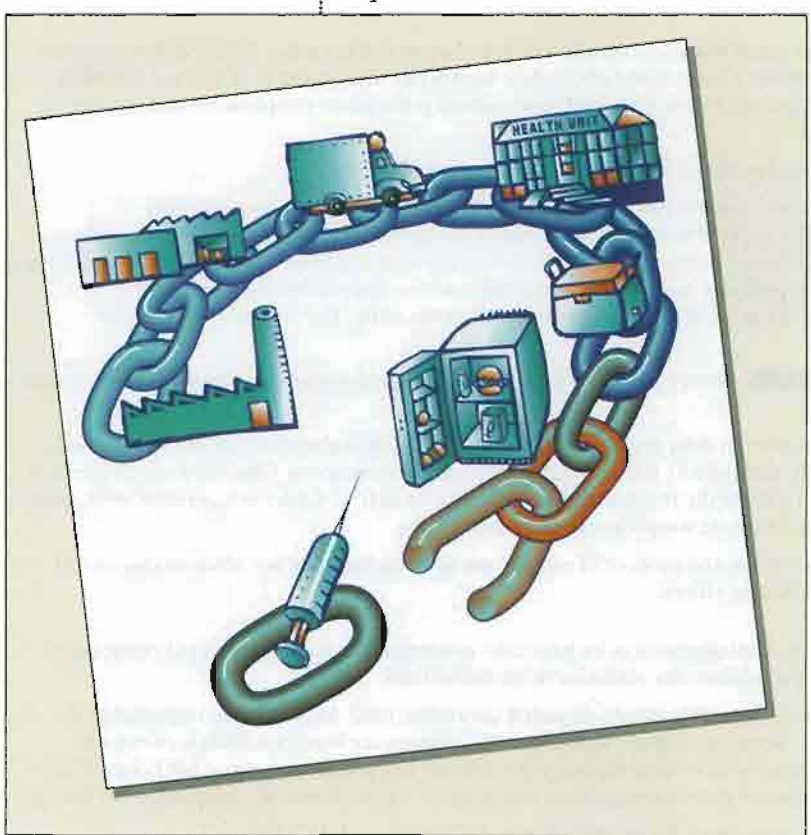
DEVELOPMENT OF EFFECTIVE vaccines has reduced the incidence of many serious infectious diseases. However, the efficacy of vaccines can be compromised by faulty transport, storage, and handling.[1] In the 1970s and again in the early 1990s, improper vaccine storage and handling were cited as possible reasons for vaccine failure that resulted in measles outbreaks in Canada.[2,3]

Vaccines vary in stability with temperature changes.[1,4-6] Tetanus and diphtheria toxoid should not be frozen[7] but are more stable at warmer temperatures than pertussis and injectable polio vaccines. Live virus vaccines, such as oral polio, can be frozen, but repeated freeze-thaw cycles should be avoided.[1] The sensitivity of various vaccines to higher storage temperatures has been reported,[8] and the adverse effects of elevated temperatures on vaccine potency are believed to be cumulative.[8] Not only are vaccines sensitive to temperature, but some, such as measles, mumps, and rubella, must always be protected from light.[7] All vaccines should be stored and handled under recommended conditions to ensure optimal potency when they are administered.



The cold chain has been extensively studied in nonindustrialized countries because of concerns about limited refrigeration facilities, power shortages, and inadequate transportation systems.[9] However, problems with the cold chain are not limited to these countries. A Montreal study reported that 60% of 20 immunization sites visited had refrigerator temperatures higher than the recommended range of 2°C to 8°C.[2] A Los Angeles study of 50 pediatric offices showed that only 16% of vaccine storage coordinators could cite appropriate temperatures for vaccines, and 11 of 50 offices had refrigerator temperatures above 8°C.[10] A British study of 40 general practices and community child health clinics showed only 40% of health care workers were aware of appropriate storage conditions for vaccines and only 20% had refrigerator thermometers.[11]

In Ontario, most vaccines are administered in physicians' offices. Basic childhood vaccines (DPTP, Hib, MMR), adult vaccines (Td, IPV), and vaccines for high-risk groups (influenza, hepatitis B) are distributed at no cost to physicians by the provincial Ministry of Health. Physicians practising in metropolitan Toronto can order vaccines directly from the Ontario Government Pharmacy; physicians practising outside this region must order their vaccines from local health departments. In 1993, the value of vaccines distributed for Ontario's publicly funded immunization programs was about $26 million. Office visits, vaccine administration, and vaccine transportation all raise the cost of this publicly funded vaccine program even higher.

International literature suggests that insufficient attention is paid to vaccine handling and storage in many countries,[5,9-11] but only one Canadian study has been published on the subject.[2] In recognition of the importance of the

cold chain in maintaining vaccine potency, this study was conducted to assess the knowledge and practice of vaccine handling and storage in primary care physicians' offices.

METHODS

A cross-sectional survey of primary care physicians' practices (general practitioners and pediatricians) was undertaken from August to December 1992. Interviewers visited primary care practices, administered the questionnaire, and inspected the vaccine refrigerator. Outside metropolitan Toronto, 11 of 36 self-selected Ontario public health departments contacted 116 primary care practices. Participants were chosen by selecting every 10th practice that regularly ordered vaccines through the health department. In metropolitan Toronto, we contacted 40 randomly selected primary care physician practices affiliated with a teaching hospital.

Interviewers telephoned physician practices to arrange visits. Offices were not informed about refrigerator inspections in order not to bias findings during the visit. The questionnaire was administered to the individual in each office with the greatest responsibility for vaccine storage and handling. Then physicians were interviewed about their sources of information about vaccines, and permission was requested to inspect refrigerators. Inspectors measured the refrigerator's interior temperature with a food-probe thermometer, noted the presence of food and drink, examined vaccine placement, and recorded amounts of expired vaccines.

Practices outside metropolitan Toronto were analyzed separately from practices inside. Participating practices outside metropolitan Toronto were mainly general practices, whereas participating practices inside the city were both general and pediatric practices. Statistical analysis involved one-way analysis of variance (ANOVA), χ^2 tests, and Fisher's exact test when expected cells were less than 5. Epi Info version 5.01B software[12] was used for the analysis.

RESULTS

Of 156 practices contacted, 135 (86.5%) participated in the study. Practices outside metropolitan Toronto were more likely to participate than practices inside. Of 116 selected practices outside metropolitan Toronto, 110 (94.8%) enrolled; of 40 selected inside the city, only 25 (62.5%) enrolled ($P<0.001$).

Outside metropolitan Toronto, 107 (94.7%) of 113 selected general practices and three (100%) selected pediatric practices entered the study. Of 66 group practices approached, 60 (90.9%) participated; all 50 solo practices approached participated. Practices in communities with more than 5000 inhabitants were as likely to participate as practices in smaller communities (94.2% versus 96.7%).

Inside metropolitan Toronto, 16 (64%) of 25 selected general practices and nine (60%) of 15 selected pediatric practices agreed to participate. Seven (63.6%) of 11 group practices approached and 18 (62.1%) of 29 solo practices approached enrolled in the study.

Practices outside metropolitan Toronto

Sixty-three (59.8%) general practices and all three pediatric practices were solo practices. Seventy-eight (72.9%) general practices and all pediatric practices were located in communities with more than 5000 inhabitants. Physicians had been in practice for a mean of 13.5 years in group settings (range 2 to 30 years, SD 8.2 years) and 14.6 years in solo settings (range 1 to 54 years, SD 10.3 years).

In 40 (90.9%) of the 44 group practices and 62 (93.9%) of the 66 solo practices, a single person was responsible for vaccine ordering and storage. Written duties for this person were

available in only six (13.6%) group practices and six (9.1%) solo practices. In group practices with a single vaccine coordinator, this person was the nurse in 32 practices (80.0%) and the secretary in five (12.5%). In solo practices with a single vaccine coordinator, the nurse was the vaccine coordinator in 31 (50%) and the secretary in 23 (37.1%). Physicians had this responsibility in only four of 102 practices, but physicians administered vaccines in 17 (38.6%) group practices and 39 (59.1%) solo practices.

Knowledge and self-reported practice. Responses to the questionnaire differed only slightly between group and solo practices with one exception. Group practices more frequently reported storage of vaccines on the doorshelves of refrigerators than solo practices. Only 12 (27.3%) group practices reportedly never stored vaccines on doorshelves compared with 37 (56.1%) solo practices. Results are reported for group and solo practices combined; subgroup results are shown in *Tables 1 and 2*.

Ninety-two (83.6%) vaccine coordinators knew that heat was harmful to all vaccines, 30 (27.3%) that freezing was harmful to some vaccines, and 50 (45.5%) that light was harmful to some vaccines. Thirty-eight (34.5%) were aware of the "shake test" as a means of determining whether diphtheria, pertussis, and tetanus (DPT) vaccine had been previously frozen. However, only six (5.5%) answered all the questions correctly. Sixty-three (57.3%) individuals correctly specified the optimal temperature range for vaccine storage.

Only 12 (10.9%) refrigerators were used exclusively for vaccine storage; 98 (89.1%) were also used to store food, laboratory specimens, and medications. A thermometer was present in 11 (10%) refrigerators, and the temperature was checked at least once a week in five (45.5%) of them. One hundred (90.9%) practices always arranged old and new vaccines to facilitate the use of older vaccines first.

Vaccines arriving at the office were kept at room temperature for an average of 1 minute (range 0 to 30 minutes, SD 5.6 minutes) before being transferred to refrigerators. During use, vaccines were left outside the refrigerator for a mean of 4.4 minutes (range 0 to 30 minutes, SD 7 minutes) in group practices and 2.5 minutes (range 0 to 60 minutes, SD 8.2 minutes) in solo practices. These results do not include one group and one solo practice, which each reported leaving vaccines outside the refrigerator for as long as 8 hours during use.

Information for physicians. Sixty-six (60%) physicians cited information received from the Ontario

Table 1. **Correct responses* to questions about vaccine storage and handling**

	OUTSIDE METROPOLITAN TORONTO†		WITHIN METROPOLITAN TORONTO	
QUESTIONS	GROUP PRACTICE (N = 44) (%)	SOLO PRACTICE (N = 66) (%)	GROUP PRACTICE (N = 16) (%)	SOLO PRACTICE (N = 9) (%)
Is heat harmful to vaccines?	79.5	86.4	75	100
Is freezing harmful to some vaccines?	34.1	22.7	25	44.4
Is light harmful to some vaccines?	50	42.4	43.8	55.5
Are you aware of the "shake test?"	36.4	33.3	31.2	44.4
Correct response to all questions	6.8	4.5	0	11.1

** $P > 0.05$ for all responses.*

† 97.3% were general practices.

Ministry of Health as their primary source of vaccine storage and handling requirements. Other common sources were product information sheets and the *Canadian Immunization Guide*.[7] Forty-seven (42.7%) physicians learned about vaccine storage and handling in medical school and 38 (34.5%) during internship and residency. When they had specific questions about vaccines, more than 80% of physicians called the public health department.

Practices inside metropolitan Toronto

Ten (62.5%) general and eight pediatric practices (88.9%) were solo practices. Because the proportion of group and solo practices differed only slightly by type of practice, comparisons were made between general and pediatric practices without stratification for practice setting. In 15 (93.8%) general and eight (88.9%) pediatric practices, a single person was responsible for vaccine ordering and storage: the secretary in six (40%) general practices and four (50%) pediatric practices. In 14 (87.5%) general and seven (77.8%) pediatric practices, the physician administered vaccines. Responses did not differ significantly between general and pediatric practices; results are reported for both practices combined. Separate results for general and pediatric practices are shown in *Tables 1 and 2*.

Knowledge and self-reported practice. Twenty-one (84%) vaccine coordinators knew that heat was harmful to all vaccines, eight (32%) that freezing was harmful to some, and 12 (48%) that light was harmful to some; nine (36%) were aware of the "shake test." Only one person (in a pediatric practice) answered all four questions correctly.

Everyone interviewed stated that vaccines were immediately placed in the refrigerator on delivery. However, four (16%) practices left vaccines outside the refrigerator for 3 to 5 hours during use. Eighteen (72%) practices always stored old and new vaccines separately, and 15 (60%) practices never stored vaccines on refrigerator doorshelves. None of the refrigerators had thermometers.

Information for physicians. The three most common sources were product information sheets cited by 11 (44%) physicians, medical training cited by seven (28%), and information received from the Ontario Ministry of Health reported by three (12%).

Table 2. **Self-reported vaccine storage and handling practices**

PRACTICES	OUTSIDE METROPOLITAN TORONTO*		WITHIN METROPOLITAN TORONTO	
	GROUP PRACTICE (N = 44) (%)	SOLO PRACTICE (N = 66) (%)	GROUP PRACTICE (N = 16) (%)	SOLO PRACTICE (N = 9) (%)
Refrigerator used exclusively for vaccine storage	9.1	12.1	18.8	22.2
Thermometer in refrigerator	13.6	7.6	0	0
Old and new vaccines organized to facilitate use of older vaccines first (always)	88.6	92.4	75	66.7
Vaccines never stored on refrigerator doorshelves	27.3†	56.1†	62.5	55.5

** 97.3% were general practices.*
† $P < 0.05$

Refrigerator inspections in all practices

The average age of inspected refrigerators was 8.6 years (range 1 to 50 years, SD 6.9). Forty-three (31.9%) refrigerators had temperatures outside the recommended range of 2°C to 8°C: eight (5.9%) had temperatures below 2°C and 35 (25.9%) had temperatures above 8°C.

The older the refrigerator, the higher the mean temperature (5.5°C if refrigerator was < 10 years, 6.4°C between 10 and 19 years, 6.5°C between 20 and 29 years, and 10°C ≥ 30 years, $P > 0.5$). Refrigerators older than 12 years were much more likely to have inappropriate temperatures (52.2% versus 26.4%, $P = 0.018$) and to have detectable seal breaks (100% versus 0%). Seal breaks were detectable in 40% of refrigerators with inappropriate temperatures compared with 20% of those with appropriate temperatures ($P = 0.2$).

Reported behaviours correlated well with refrigerator inspections. Vaccines were less often found on the door-shelves of refrigerators when coordinators reported they never were (32.8% versus 80.3%, $P < 0.001$). Food and drink were much less likely to be found when lunches were reportedly not stored in the refrigerator (37.2% versus

Figure 1. **Ontario Ministry of Health vaccine storage and handling guidelines**

OFFICE ORGANIZATION

1. Designate one person to be responsible for the care of vaccines. This person should be made aware of proper techniques. Written guidelines are recommended to ensure consistency of practices during staff absences and turnover.
2. Review procedures regularly. Be prepared to answer staff questions about procedures.

ORDERING VACCINES

3. Check the vaccine supply on the first or last working day of every month.
4. Maintain a 1- to 3-month vaccine supply in your refrigerator.
5. Review the vaccine invoice (if available) to determine the dollar value of vaccine used by your office. Ensure that all staff are aware of the cost of these products.

STORING VACCINES

6. Store all vaccines between 2°C and 8°C.
7. Check and record refrigerator temperature twice daily using a maximum-minimum thermometer and logbook. Obtain servicing for malfunctioning refrigerators promptly, or replace if required.
8. Ensure that refrigerator is not crowded and that air can circulate around products. Ideally, the refrigerator should be only half full.
9. Avoid storing nonmedical items in refrigerator (eg, staff lunches, beverages) to reduce temperature fluctuations that occur with frequent door opening.
10. Do not store vaccine on the refrigerator door shelf where temperature fluctuations are common.
11. Store short-dated products in front of longer-dated products. This will minimize expiry of product prior to use.

HANDLING VACCINES

12. Never leave vaccines unrefrigerated. Remove vaccine from refrigerator only for immediate withdrawal of a dose for immunization. Return unused vaccine to refrigerator immediately.
13. Record the date on all multidose vials when first opened; consult the direction insert to determine how long an opened multidose vial can be used.

TRANSPORTING VACCINE

14. Store ice packs in the freezer for use in insulated containers during vaccine transport. This will also stabilize refrigerator temperatures during power shortages and refrigerator failures.
15. Do not place ice packs directly on vaccine packages during transport to avoid freezing.
16. Wrap vaccines in paper for extra insulation during transport requiring more than 10 minutes.
17. Place a thermometer in the insulated container to monitor temperature during vaccine transport.

DISPOSING OF VACCINES

18. Vaccines expire at the end of the month listed (eg, a vaccine expiry date of Sept/95 means September 30, 1995).
19. Ask your local public health department about how to dispose of vaccine. This will allow for safe disposal of expired or mishandled vaccine for better monitoring of vaccine use.

ADVICE ABOUT VACCINES

20. Contact your local health department for advice about use of vaccines that have been exposed to temperatures outside the recommended range of 2°C to 8°C. Vaccines that have been mishandled should be stored at 2°C to 8°C until advice is obtained.

79.0%, $P < 0.001$). Old and new vaccines were well separated in refrigerators when this practice reportedly occurred (88.9% versus 64.3%, $P = 0.025$).

The amount of expired vaccines found during inspection was calculated as a proportion of the total amount of the product in the refrigerators. The highest proportion of expired product was found for inactivated polio vaccine (34%), rubella vaccine (18%), and oral polio vaccine (11.5%).

DISCUSSION

The overall response rate was 86.5% for this study. Practices outside metropolitan Toronto were more likely to participate than practices inside. Practices outside metropolitan Toronto, which routinely ordered vaccines from public health departments, were likely familiar with the department that requested their participation. This factor probably accounted for the much higher response rate seen outside metropolitan Toronto.

Findings from this study were consistent with other studies that found problems with vaccine storage and handling.[2,10,11] Results were consistent between practices inside and outside metropolitan Toronto, between group and solo practices, and between general and pediatric practices. Only seven of those interviewed knew the effects of heat, freezing, and light on vaccines. Only 11 refrigerators had thermometers. Approximately 70% of practices stored food and drink with vaccines, and 40% to 70% of practices stored vaccines on refrigerator doorshelves at least some of the time.

One most worrying finding was the 43 refrigerators with temperatures outside the recommended range of 2°C to 8°C. Vaccines have different tolerances to temperature fluctuations, and the effect on potency will depend on the type of vaccine and the length of time it is inappropriately stored. A study that tested 107 samples of live polio, measles, and rubella vaccine from different clinics in the United States reported that 20 (19%) showed significant loss of potency (defined as a difference in potency of more than 2 SD between field and retained samples) compared with similar vaccine stored under appropriate temperatures by the Bureau of Biologics.[5]

Older refrigerators were especially likely to have higher temperatures and to have detectable seal breaks on the doors. Findings from this study emphasize the need for routine temperature monitoring in all refrigerators. This is especially critical when refrigerators are more than 12 years old because more than half the ones checked in our study had temperatures above 8°C. When refrigerators can no longer maintain temperatures between 2°C and 8°C, they need to be serviced or replaced.

The presence of expired vaccines is also worrying. These vaccines might have compromised potency and could be inadvertently administered to patients if expiry dates are not carefully checked before use. Products with earlier expiry dates should be stored in front of products with later expiry dates to facilitate their use and to minimize vaccine wastage. Expiry dates of vaccines should be checked periodically and expired vaccines returned to suppliers.

Self-reported behaviours correlated well with refrigerator inspections, but findings were generally less favourable than suggested by respondents. For example, vaccines were found on the doorshelves of refrigerators in one third of practices that claimed never to place them there. Perhaps respondents describe better practices than exist, or perhaps vaccine coordinators only described their own behaviour. Other people in the office who have access to vaccines and to the refrigerator might have different practices.

Product information sheets, provincial government information sheets, and the *Canadian Immunization Guide*[7] were physicians' usual educational

resources about vaccines. However, responsibilities for vaccine ordering and storage were often delegated to nonphysicians. Because different individuals had different responsibilities for vaccine ordering, storage, and administration, educational initiatives need to be targeted to anyone in a practice involved with these activities. *Figure 1* gives 20 practical suggestions on vaccine storage and handling. Physicians might wish to post it for convenient reference for all office staff.

The strength of this study lies in verification of self-reports with refrigerator inspections. The limitation of the study lies in potential selection biases introduced by involving only health units that agreed to provide staff for site visits and by selecting Toronto physicians affiliated with a single teaching hospital. Findings from the few pediatric practices enrolled in this study might not be representative of other pediatric practices.

This study highlights serious problems with vaccine storage and handling in primary care offices in Ontario. While results cannot be generalized to the rest of Canada, they suggest that vaccine storage and handling warrant further study in other jurisdictions. Immunization is an important means of controlling serious infectious diseases, and careful attention to vaccine storage and handling is essential to ensure optimal vaccine effectiveness. ■

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