Table 1—*Number of vaccine refrigerators with unacceptable temperatures at baseline and follow up in general practices in Western Australia, October 1994 to January 1995*

	Unacceptable at baseline	Unacceptable at follow up	Improved	Deteriorated
Intervention (n = 25)*	12	3	10	1
Control (n = 25)†	6	9	2	5

*P = 0.02, † not significant; McNemar's test.

probability of a refrigerator being acceptable, accounting for group status (control or intervention) and repeated measurements (baseline and follow up).

Of the 36 metropolitan practices randomly selected, 29 were eligible and 25 agreed to participate. Of the 28 rural practices identified, all 25 eligible practices agreed to participate, giving a total of 50 practices. Only five of the staff members responsible for vaccine storage in these 50 practices knew the recommended maximum and minimum temperatures for vaccine storage and only two knew which vaccines were damaged by freezing.

Changes in the acceptability of refrigerator temperatures at baseline and follow up are shown in table 1. Logistic regression analysis showed that the odds ratio of a refrigerator in the intervention group being acceptable at follow up relative to baseline was 6.8 (95% confidence interval 1.9 to 24.3), while in the control group the odds ratio was 0.6 (0.2 to 1.7). The interaction between group status and acceptable temperature at follow up was statistically significant ($\chi_1^2 = 8.4$; P = 0.004). Of the 30 unacceptable refrigerator recordings at baseline and follow up, 26 recorded more than one hour below –0.5°C.

Comment

Eighteen (36%) practice refrigerators recorded unacceptable temperatures at baseline: most of these refrigerators recorded temperatures that may have frozen vaccines and consequently damaged them. The staff members responsible for vaccine storage had poor knowledge about recommended temperatures and were unaware of their refrigerator's temperatures. This randomised controlled trial shows that educating a staff member in each practice on correct vaccine storage conditions and nominating that staff member to monitor the refrigerator's temperature with a digital maximum-minimum thermometer improved vaccine storage. Selection bias was minimised as only four eligible practices refused to participate. Blinding was considered unnecessary as recordings were by a computerised device, and though only a small sample was studied a significant improvement was nevertheless observed. The widespread implementation of this simple and inexpensive intervention should result in better vaccine storage conditions and fewer vaccine failures in general practices.

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Conflict of interest: None.

1 Haworth EA, Booy R, Stirzaker L, Wilkes S, Battersby A. Is the cold chain for vaccines maintained in general practice? *BMJ* 1993;307:242-4.
2 Thakker Y, Woods S. Storage of vaccines in the community: weak link in the cold chain? *BMJ* 1992;304:756-8.
3 Galazka A. *World Health Organisation expanded programme on immunisation—stability of vaccines*. Geneva: WHO, 1989.
4 World Health Organisation. Tests of the freezing point of vaccines. *EPI Cold Chain Newsletter* 1990:90:4-5.
5 Breslow NE, Clayton DG. Approximate inference in generalised linear mixed models. *Journal of the American Statistical Society* 1993;88:9-25.

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High ambient temperature: a spurious cause of hypokalaemia

P W Masters, N Lawson, C B Marenah, L J Maile

During the exceptionally hot summer of 1995 we noticed an increase in the number of cases of hypokalaemia reported by this laboratory among patients seen in general practice, though quality control data showed that the laboratory's methods and performance had not changed. Samples are collected from surgeries once a day and delivered by van to the laboratory, often several hours after venepuncture. We postulated that the high ambient temperature in the interim was directly responsible for the increase in hypokalaemia by stimulating cellular uptake of potassium.

Subjects, methods, and results

Daily means for plasma potassium concentrations for samples from this hospital and general practices were obtained separately from the laboratory computer for the period 1 January to 10 August 1995. These means were compared with the maximum daily dry bulb temperatures recorded at the Nottingham and Warsop weather stations (data were supplied by the Meteorological Office at Bracknell).

Venous blood was collected from five healthy, non-fasting volunteers at 9 am and aliquoted into Vacutainers (Becton Dickinson, Oxford) containing lithium heparin. Samples were kept unseparated at 4°C, 37°C, and 23°C (the temperature of an airconditioned room). Plasma potassium was measured on an Olympus AU 800 analyser after 0, 4, and 24 hours. Changes at the higher temperatures were investigated further with another 10 volunteers, storing aliquots at 23°C and 37°C and measuring potassium after 0, 0.5, 1, 2, 3, 4, 5, and 8 hours. The effect of continuous sample mixing, as might occur during transit in a van, was investigated with samples from a further five volunteers, divided equally between two 37°C water baths, one with motorised sample agitation. Differences were compared to baseline by analysis of variance; results from different experiments were combined when measurements were made at the same temperature and time points.

The daily mean potassium concentration for hospital patients was relatively constant over the period 1 January to 30 June, with a slight fall in July and August (fig 1). The daily mean for general practice patients, however, was highly significantly correlated with maximum daily temperature (r = –0.91, P<0.0001). The widest divergence between the two populations coincided with the highest temperatures.

In all the stability experiments, baseline potassium concentrations were in the range 3.83–4.50 mmol/l. Potassium rose rapidly when samples were kept at 4°C, as previously reported.[1,2] After 4 hours the mean rise was 1.00 mmol/l (95% confidence interval 0.56 to 1.44; P<0.001). At 23°C potassium did not change significantly for up to 8 hours. After 24 hours, however, there was a mean increase of 1.12 mmol/l (0.87 to 1.37; P<0.001). At 37°C potassium showed a small initial fall of –0.22 mmol/l at 4 hours (–0.44 to –0.01; P<0.001) but a rise at 24 hours of 6.27 mmol/l (6.02 to 6.53; P<0.001). No differences were found between agitated and static samples.

Comment

Delayed sample separation is a well recognised cause of spurious hyperkalaemia. In hot weather it should be

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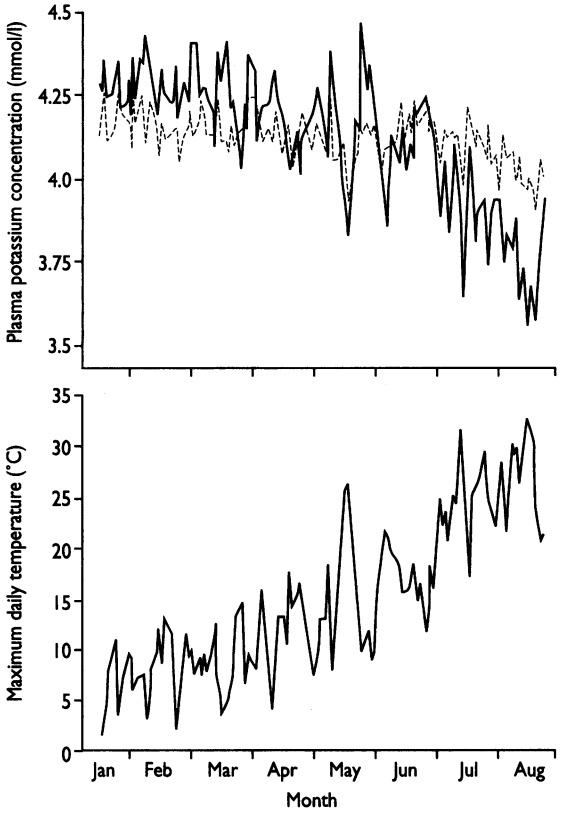

Fig 1—*(Top) daily mean potassium concentrations from hospital patients (dotted line) and patients from general practice (solid line); (bottom) maximum daily temperature*

considered in the differential diagnosis of hypokalaemia. Laboratories and clinicians should be aware of this phenomenon so that results may be confirmed before starting unnecessary investigations and treatment. The corollary is that there may also be an increased prevalence of pseudonormokalaemia in patients who have true hyperkalaemia.

The apparent stability of potassium at 23°C is in agreement with a previous study which reported no change over 16 hours at 18°C.[3] Another report indicates, however, that potassium concentration may fall by a mean of 0.22 mmol/l in 2 hours at 25°C.[4] In vitro changes in potassium are more complex than is usually stated in textbooks.[5] The exact timing and temperature are clearly critical in determining the result that is actually reported by the laboratory.

We thank the laboratory staff of the department of clinical chemistry for volunteering as subjects and for performing the potassium measurements.

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Conflict of interest: None.

1 Goodman JR, Vincent J, Rosen I. Serum potassium changes in blood clots. *Am J Clin Pathol* 1954;24:111-3.
2 Moore D, Walker P, Ismail A. The alteration of serum potassium level during sample transit. *Practitioner* 1989;233:395-7.
3 Verrensen L, Lins RL, Neels H, De Broe ME. Effects of needle size and storage temperature on measurements of serum potassium. *Clin Chem* 1986;32:698-9.
4 Kalsheker N, Jones N. Inaccurate in vivo plasma potassium measurements due to in vitro changes in unseparated blood. *Clin Chem* 1984;30:1581-2.
5 Tietz NW, Pruden EL, Siggaard-Andersen O. Electrolytes, blood gases and acid-base balance. In: Tietz NW, ed. *Textbook of clinical chemistry.* Philadelphia: Saunders, 1986:1176-7.

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Commentary: Replication of results

M D Buckley-Sharp, D A Gardner

The phenomenon of high ambient temperature causing a factitious hypokalaemia is not described in the usual textbooks and seems to be largely unknown. If it is so easily demonstrated, even in a temperate climate, then it should be equally easily repeatable.

We recovered all plasma potassium results from 1 January to 30 September 1995, divided them into two groups according to their origin (general practice and other), and calculated the mean and standard deviation for each group for each day. There were no results from general practice for Saturdays, Sundays, or holidays, and samples with these dates were removed for both groups. Over the 189 working days, there remained 6191 results from general practice and 81 496 results from other sources. After reviewing the data, we thought that the clearest presentation would be given by graphing the five day rolling average of the daily means, and these are shown in figure 1.

The important features of these results are all in agreement with Masters *et al.* Results from general practice were usually higher than results from other sources. From late June there was a steady fall in the mean of results from general practice. By late July, mean results from general practice were lower than mean results from other sources. As our data series is longer than that of Masters *et al*, we observed a return towards the more usual comparison by late September. The difference in spring, and the amount of the summer reduction in results from general practice, are both quantitatively similar to the results of Masters *et al.* Our results were obtained with three separate ISP1000 analysers, and the changes cannot be explained by standardisation or quality variation.

It is supposed that the lowered plasma potassium concentration is caused by high temperature incubation of the samples, especially in a closed van on a hot day. Some of our samples in the general practice group did not arrive by van, while some samples from other sources did. This may explain some correlation between the two data series—as seen in August, for example.

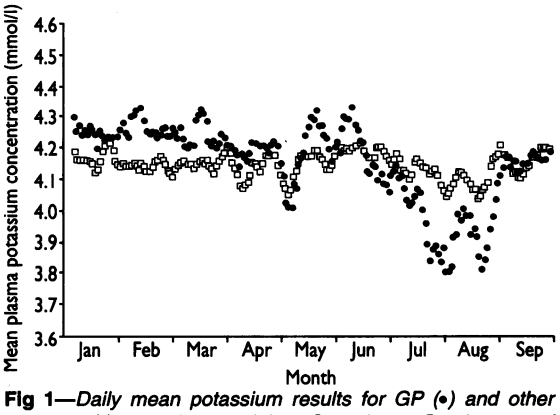

Fig 1—*Daily mean potassium results for GP (•) and other sources (▫) samples, omitting Saturdays, Sundays, and holidays, shown as five day rolling averages, 1 January to 30 September 1995*

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