Management of Severe Hypokalemia in Hospitalized Patients

A Study of Quality of Care Based on Computerized Databases

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Background: While administrative databases are used to assess general indicators of quality of care, a detailed audit of the process of clinical care usually requires review of hospital medical records.

Objective: To evaluate the feasibility of assessing the management of severe hypokalemia using computerized administrative and laboratory databases.

Methods: The study included all patients hospitalized in 1997 who experienced serum potassium levels of less than 3.0 mmol/L at Hadassah University Hospital, Jerusalem, Israel, a tertiary care center. Using the computerized databases, we measured the following: (1) whether a subsequent serum potassium test was performed, (2) time to the subsequent test and to normalization of the serum potassium level, (3) achievement of normokalemia, and (4) in-hospital mortality. In a random subsample of 100 patients, these measures were compared with the blinded assessment of the quality of medical management of hypokalemia, as determined from medical records, using predetermined criteria for adequate management.

Results: The computerized databases revealed that severe hypokalemia occurred in 866 patients (2.6% of the yearly hospitalizations): 55 patients (6.4%) had no subsequent serum potassium levels measured, and 260 (30.0%) were discharged from the hospital with a subnormal potassium level. The mean time to a subsequent test was 20 hours, and to normokalemia, 50 hours; both intervals varied by department. In-hospital mortality was 20.4%, or 10-fold that of the entire hospitalized population. A review of hospital medical records revealed inadequate clinical management of hypokalemia in 24%, which was associated with nonperformance of a subsequent test (likelihood ratio, 8.4), failure to normalize the serum potassium level (likelihood ratio, 4.2), discharge from the hospital with a subnormal potassium level (likelihood ratio, 2.1), and in-hospital death (likelihood ratio, 2.5), all of which could be determined by the computerized databases.

Conclusions: The computerized laboratory database is useful in ascertaining the prevalence of severe hypokalemia and in assessing shortcomings in its management. Databases can be used to derive valid and efficient measures of the quality of the clinical management of electrolyte disorders.

Arch Intern Med. 2001;161:1089-1095

EVALUATION of the quality of care is increasingly recognized as an essential aspect of medical practice. Methods to evaluate medical care range from peer review based on medical record audit to quality assessment based on computerized databases. The former, while having the potential to be highly detailed and specific, is costly in terms of time and other expenses and potentially includes biases in judgment. The latter may be hampered by poor specificity and a limited ability to adjust for case mix. All clinical audits or quality assessment measures are dependent on the quality of data entry. Assessments based on data that are entered automatically, such as laboratory databases, should theoretically contain data of higher reliability than other sources. Until now, computerized audits have mainly been used to assess general indicators of quality, such as postoperative death or early readmission, but have rarely been used for the detailed assessment of the management of specific clinical conditions.

Electrolyte abnormalities are common in hospitalized patients. They frequently occur as iatrogenic complications of medications and medical procedures. Recent studies1-4 from Europe and North America have shown that the management of these common abnormalities is frequently suboptimal. Hypokalemia is defined as a serum potassium level of less than 3.5 mmol/L. It can be life threatening when severe, due to its asso-

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PATIENTS AND METHODS

PATIENTS

Using the laboratory database, we identified all patients hospitalized in 1997 in Hadassah Ein Karem (a 650-bed teaching hospital in Jerusalem, Israel, providing tertiary care services) who experienced at least 1 event of hypokalemia with a serum potassium level of less than 3.0 mmol/L. This is the critical level below which the laboratory notifies the physician or ward by telephone. Only the first episode of severe hypokalemia per hospitalization was considered; however, some patients experienced more than 1 such hospitalization during the year. In our hospital, most blood tests are performed by the physicians themselves.

DATA SOURCES

From the laboratory database, we extracted data on patient identification number and date, time, and value of the first test showing a serum potassium level of less than 3.0 mmol/L. For each case identified, all subsequent potassium test results for that individual were extracted. From the administrative database, we extracted data on identification, sex, year of birth, date and department of admission and discharge, status at discharge from the hospital (dead or alive), and discharge diagnoses by ICD-9. (Medications and prescriptions are not available on the computerized databases.) Normokalemia was defined as a serum potassium test result between 3.5 and 5.0 mmol/L, corresponding to the laboratory standard.

We chose a random sample of 100 medical records from the population who experienced hypokalemia using random numbers derived from Statistical Product and Service Solutions software, version 6.12 (SPSS Inc, Chicago, Ill). The random sample was chosen to maintain a proportion of 20% who had more than 1 hospitalization with severe hypokalemia and 80% who experienced only 1 such hospitalization. For this sample, we analyzed the last admissions in 1997 in which severe hypokalemia occurred. These medical records were reviewed by a physician (E.S.) and nurse who were blinded as to the pattern of potassium test results. Medical records were reviewed for the presence of drugs that could be responsible for hypokalemia; occurrence of diarrhea and/or vomiting; and indicators of the medical management of hypokalemia, including mention of hypokalemia in the physician’s notes and evidence of potassium supplementation in the physician’s orders and in the medication records. The medical record review was considered the gold standard for assessing the adequacy of the clinical management of severe hypokalemia. The criteria for “appropriate management” included evidence for initiation or increase of potassium supplementation or initiation of potassium-sparing agents on the day of or day after the first episode of severe hypokalemia. Discontinuation of medication causing hypokalemia was not considered an adequate measure if not accompanied by potassium supplementation. We compared the results of the computerized databases with the results of the medical record review using the previously mentioned criteria. The probability of having a poorer outcome on computer-derived analysis (no subsequent test, failure to normalize the serum potassium level, discharge from the hospital with an abnormal serum potassium level, and in-hospital death) in those with inadequate management as per medical record review yielded estimates of the sensitivity of the computerized audit. The probability of having these poor outcomes in patients with adequate management of hypokalemia yielded estimates of the false-positive rate or 1-specificity. Likelihood ratios were calculated according to the following formula: sensitivity/(1-specificity).

STATISTICAL METHODS

Statistical analyses were performed using Statistical Product and Service Solutions software, version 6.12 (SPSS Inc) and the PEPI program.9 Dependent variables were categorical (eg, performance of a subsequent test, achievement of a normal serum potassium test result, a normal or abnormal last recorded level, and vital status at discharge from the hospital) or time continuous (eg, to performance of a subsequent test or to normalization of the serum potassium level). For most analyses, the unit of analysis was individuals, and we analyzed their last admission in 1997 in which hypokalemia was documented (N=866). When assessing length of stay and the distribution of low serum potassium test results, we analyzed all hospitalizations in 1997 in which hypokalemia occurred (N=975). The χ² test was used in univariate analysis to test associations between the dependent variables and sociodemographic and other descriptive variables. The t test was used for comparison of means. To test the representativeness of the sample chosen for medical record review compared with the total population, we used the z test and the χ² test for goodness of fit.

Multiple logistic regression analysis was used to assess the independent contribution of predictor variables (age, sex, admission department, discharge from the hospital, diagnosis, and transfer between departments) to categorical outcomes (achievement of a normal potassium test result and vital status at discharge from the hospital). Variables associated with these outcomes in univariate analysis were entered into regression models by forward stepwise selection, with an entry criterion of P≤.10. In all statistical analyses, P≤.05 (2-tailed) was considered statistically significant.

PATIENTS with cardiac disease are at especially high risk of hypokalemia-induced arrhythmias. While muscle weakness and other symptoms may be experienced by patients with hypokalemia,6 most patients are asymptomatic and, therefore, laboratory monitoring is essential. Corrective action is simple, consisting of potassium supplementation or initiation of potassium-sparing medications. There appears to be agreement that immediate potassium supplementation should be given at serum levels of less than 3.0 mmol/L,7 because of the increased risk of arrhythmias below this level.8

Given its clinical significance, ubiquity, and relatively consistent mode of treatment, the management of hypokalemia is a relevant subject for clinical audit. We decided to perform an evaluation of the quality of management of severe hypokalemia (serum potassium level <3 mmol/L) in hospitalized patients using computer-
ized databases available in our center. Our purpose was to assess the feasibility of using computerized laboratory data to evaluate the quality of medical care. The primary hypothesis of this study was that the pattern of serum potassium test results in patients with an initial level of less than 3.0 mmol/L, as retrieved from the computerized laboratory database, could be used as an indicator of the adequacy of the actual clinical management of severe hypokalemia. Our specific objectives were as follows: (1) to use the hospital's computerized databases in order to describe the pattern of potassium test results in terms of performance of a subsequent test, achievement of normokalemia, and time to a subsequent test and to normokalemia; (2) to estimate in-hospital mortality for the population with hypokalemia; and (3) to evaluate the physician's management of hypokalemia using data from the medical record in a subset of patients, and to assess whether there is an association between the physician's management based on medical record data and the pattern of potassium test results (as previously noted) retrieved from computerized databases.

RESULTS

RESULTS OBTAINED FROM THE COMPUTERIZED DATABASES

In 1997, of 37,458 admissions, there were 975 (2.6%) in which severe hypokalemia (a potassium level of <3.0 mmol/L) was recorded at least once. This represents 866 patients, of which 780 (90%) experienced severe hypokalemia on 1 admission during the year and 86 (10%) had 2 or more hospitalizations with an episode of severe hypokalemia. Of the 975 episodes, 7 (0.7%) had a serum potassium level of less than 2.0 mmol/L, 83 (8.5%) had a level of 2.0 to 2.4 mmol/L, and 885 (90.8%) had a level of 2.5 to 2.9 mmol/L. Among all 975 admissions, 274 (28.1%) were admitted with a serum potassium level of less than 2.0 mmol/L, and 701 (71.9%) developed this condition during their hospitalization. In only 17 cases (1.7%) was the diagnostic code for hypokalemia mentioned in the discharge summary or administrative database record.

Severe hypokalemia occurred at all ages and in all departments. Table 1 summarizes descriptive characteristics of affected patients. Women represented 53.5% of the hypokalemic population. The mean age was significantly older for women (P=.001) compared with men, and the sex distribution significantly differed by department (P<.001, with or without the exclusion of obstetrics and gynecology). The mean length of stay for the population with severe hypokalemia was 23.7 days (SD, 29.6 days); the median was 13 days. This is compared with a mean length of stay for the entire hospital population in 1997 of 6 days (SD, 2.0 days) (P<.001). Patients with more than 1 hospitalization in which severe hypokalemia occurred were more likely to be admitted to the hematology, oncology, and bone marrow transplantation or pediatrics department compared with others. Patients with successive admissions with severe hypokalemia were more likely to have extreme low levels (<2.5 mmol/L) of serum potassium than those with only 1 hospitalization (21% vs 7%; P=.001), and to be admitted with hypokalemia rather than developing it in the hospital (38% vs 26%; P=.02).

The management or response to hypokalemia was assessed using data from the last hospitalization in which severe hypokalemia occurred during the study period. The response to hypokalemia in terms of performance of subsequent tests, achievement of normokalemia, and potassium level at discharge from the hospital as determined by the laboratory computer database is shown in the Figure. Nonperformance of a subsequent test was rare (6.4% of the patients), but discharge from the hospital with a subnormal potassium level (<3.5 mmol/L) occurred in 30% of the patients because of failure to correct hypokalemia or recurrent decreases in the serum potassium level after initial correction. Nonperformance of a subsequent test was not associated with demographic characteristics of the patients, the timing of development of hypokalemia (on admission or during the hospitalization), or the initial potassium level. There was a borderline association with department of admission (P=.05), with the rate of performance being highest in the intensive care unit and in the internal medicine and pediatrics departments and lowest in the obstetrics and gynecology wards. No death occurred on the day that severe hypokalemia was initially recorded (day 0) such that in every case an opportunity existed to remeasure the potassium level after an extreme low value.

The achievement of normokalemia was highest in the intensive care units (93%) and in the pediatrics department (90.7%) and lowest in the obstetrics and gynecology departments (69%). Controlling for admission department and transfer between departments, the only variable found to be associated with achievement of normokalemia on logistic regression analysis was time to performance of the first subsequent test after the onset of severe hypokalemia (P=.05).

The median time to performance of the first subsequent potassium test was 13 hours (mean, 20 hours). These times were shorter in children 15 years of age and younger (mean, 17 hours; median, 9 hours) compared with adults. The more severe the hypokalemia, the shorter the time until performance of a subsequent test. For example, for a serum potassium level of 2.4 mmol/L or less, the mean and median times were 14 and 9 hours, respectively, as opposed to 20 and 14 hours, respectively, for serum potassium levels of 2.5 to 2.9 mmol/L. The shortest time from initial severe hypokalemia to performance of a subsequent test was in the intensive care units (mean, 6 hours) vs the hematology, oncology, and bone marrow transplantation units, where the median was 22 hours. The time until repetition of the test was shorter in patients who were admitted with severe hypokalemia (mean, 15 hours; median, 8 hours) compared with those who developed this condition in the hospital (mean, 22 hours; median, 17 hours) (P<.001). The mean and median times until achievement of a normal serum potassium test result were 50 and 25 hours, respectively.

Analysis of vital status at discharge from the hospital among the patient population with severe hypokalemia was more likely to have extreme low levels (<2.5 mmol/L) of serum potassium than those with only 1 hospitalization (21% vs 7%; P=.001), and to be admitted with hypokalemia rather than developing it in the hospital (38% vs 26%; P=.02).

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mia attests to the fact that this is a population at high risk of in-hospital death. The crude mortality among 866 patients, analyzing their last admissions, was 20.4% compared with 1.89% for all 37458 admissions in 1997. Factors associated with mortality on univariate analysis were department of admission (P < .001); length of stay (P = .005); initial serum potassium level (P = .01), with 31% of those with an initial serum potassium level of 2.4 mmol/L or less having died in the hospital compared with 19.4% of those with initial levels of 2.5 to 2.9 mmol/L; and achievement of normokalemia (P = .03). There was no association with age, sex, or time of onset of hypokalemia. In a multivariate model (Table 2), admission department, initial serum potassium level, number of admissions in which severe hypokalemia was documented, and length of stay remained significantly associated with vital status at discharge from the hospital, while achievement of normokalemia was no longer associated with mortality.

RESULTS OBTAINED FROM MEDICAL RECORD REVIEW

The random sample of 100 patients whose medical records were reviewed was similar to the total population with hypokalemia for sex; age distribution; department of admission and discharge; transfer within the hospital; median length of stay; ICD-9 diagnoses of diabetes mellitus, ischemic heart disease, leukemia, and kidney disorders; and status at discharge from the hospital (Table 1). They were also similar to the entire population for timing of development of severe hypokalemia (on admission or during the hospitalization), initial serum potassium level, and achievement of normokalemia. In the sample, 11 (11%) patients did not have a subsequent test performed after an initial serum potassium level of less than 3.0 mmol/L, as opposed to 55 (6.4%) patients in the entire population (P = .06). Furthermore, in the sample, 38 (38%) of the patients had a last recorded serum po-

<table>
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<th>Variable</th>
<th>Entire Study Population (N = 866)</th>
<th>Total (N = 100)</th>
<th>Adequate (n = 76)</th>
<th>Inadequate (n = 24)</th>
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<td>4 (16.7)</td>
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<td>≤2.4</td>
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<td>2.5-2.9</td>
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<td>On admission</td>
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<td>25 (25.0)</td>
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<td>73 (96.1)</td>
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<td>21 (21.0)</td>
<td>9 (11.8)</td>
<td>12 (50.0)</td>
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*Data are given as the number (percentage) of patients. Percentages may not total 100 because of rounding. HOT indicates hematology, oncology, and bone marrow transplantation; OBGYN, obstetrics and gynecology.
The computerized record was able to provide estimates of a long length of stay and a high risk of in-hospital death. and associated with potassium-depleting medications. Most cases were hospital acquired (72%) and in 24% it was not. Potassium was administered intravenously in 57 cases and orally in 50 (not mutually exclusive).

Table 3 shows the association of outcomes as determined by the computerized audit with appropriateness of response to hypokalemia as determined by the medical record audit. As shown, these indicators are highly associated. Likelihood ratios for all 4 computer-derived measures were greater than 1. Specifically, the likelihood of a patient with no subsequent test performed would have inadequate management of his or her hypokalemia according to the medical record was 8.4 times higher than the likelihood of a similar patient who received appropriate management. Furthermore, there are strong associations between appropriate management as determined by the medical record and achievement of normokalemia and discharge from the hospital with hypokalemia, and there are associations between appropriateness of management and in-hospital mortality.

In our study, severe hypokalemia occurred in 2.6% of the hospitalized patients as assessed by the computerized laboratory database. Most cases were hospital acquired (72%) and associated with potassium-depleting medications (75%). Patients who experienced severe hypokalemia had a long length of stay and a high risk of in-hospital death. The computerized record was able to provide estimates of the prevalence of hypokalemia in this hospitalized population and clues to its management. The medical record review uncovered deficiencies in the management of hypokalemia, which were predictable by the pattern of potassium test results obtained via audit of the laboratory computer database. Although the sensitivities of the computerized measures were not high, the likelihood ratios point to the ability of the computer-derived measures to identify patients with suboptimal clinical management of hypokalemia.

Severe hypokalemia (a potassium level of <3.0 mmol/L) has been previously reported in 5.2% and 3.5% of hospitalized patients. In a Scottish series, 56% of the cases of hypokalemia could be attributed to medication, especially corticosteroids, insulin, and antibiotics (as opposed to 75% in ours), and mortality varied between 20% and 34%, depending on the severity of hypokalemia. This mortality rate was remarkably similar to that in our series, in which 31.9% of those whose serum potassium level was less than 2.4 mmol/L died, compared with 19.4% of those with a minimal serum potassium level of 2.5 to 2.9 mmol/L. Even at less extreme levels of hypokalemia, a dose response has been observed between preoperative potassium levels and perioperative deaths in patients undergoing cardiac surgery.

Despite the fact that it is a common condition that frequently develops in the hospital (50% in an Austrian series and 72% in ours), few researchers have studied the management of hypokalemia in hospitalized patients. One reason for this lack may be that the data required for this are difficult to obtain from medical records—they are often missing, incomplete, or illeg-
Normalities are frequent. Acker and colleagues per-
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hospital3 and the other in an intensive care unit,4 showed
similar shortcomings. Polderman and colleagues 4 (in a
study in which hypernatremic cases were identified from
computerized databases).

Our findings appear to be similar to those of other
studies assessing management of electrolyte disorders in
different settings. Tate and colleagues19 found that the
baseline management of disorders of sodium, potas-
sium, and glucose as assessed by medical record review
was inappropriate in 31.9% of cases. Two recent audits
of the management of hypernatremia, one in a general
hospital8 and the other in an intensive care unit,6 showed
similar shortcomings. Polderman and colleagues4 (in a
study in which hypernatremic cases were identified from
the computer and the assessment of quality of care was
by medical record review) found that inadequate steps
were taken to prevent this abnormality even though there
were early signs of its development. Correction was faster
when patients were admitted with the condition, com-
pared with those who developed it during their hospi-
talization. These findings are similar to ours, and indi-
cate that more attention is paid to admission laboratory
results than to changes and complications that occur dur-
ing the hospitalization, even though hospital-acquired ab-
normalities are frequent. Acker and colleagues1 performed
an audit of the management of hyperkalemia by
medical record review and found, as we did, that treat-
ment times and adequacy of treatment were better in the
intensive care units than in the other wards. Moreover,
their findings resembled ours in that they found that the
more severe the hyperkalemia, the shorter the time to
treatment. Disappointingly, an intervention designed by
these researchers to improve the management of hyper-
kalemia by providing written guidelines to the ward had
no effect.7

Few researchers have examined the time until cor-
rection of the abnormal laboratory results. Kuperman and
colleagues16 reported a study in which critical values were
obtained from the computer and assessment of out-
comes was by medical record review. They found that
the median time to resolution for various laboratory ab-
normalities was 14.3 hours, but the specific times for cor-
rection of hypokalemia were not reported.

In our study, computer-derived indicators, such as fail-
ure to perform a subsequent test and failure to achieve a
normal serum potassium value, were highly associated with
inadequate physician response and treatment, as derived
from the medical record. Thus, they could easily serve as
indicators for shortcomings in the quality of care. Com-
puterized databases are increasingly being used to evalu-
ate the quality of medical care. Routinely collected data,
such as those included in the National Health Service mini-
num data set, can be used for clinical audit of process and
outcome and for case finding.17 On the other hand, inac-
curacies and artifacts (such as “code creep”) limit the abil-
ity to make valid assessments of quality and especially to
compare treatment standards across hospitals.18 Comput-
erized assessments, while sensitive to the occurrence of each
case of hypokalemia, are not sensitive to the nuances of clini-
cal management, such as decisions to take a less aggres-
sive approach in terminally ill patients. As such, comput-
erized audits may underestimate the actual quality of care
delivered. These factors, however, are probably less rel-
ent in the case of electrolyte disturbances, since presum-
ably if the test was performed, there is still interest in learn-
ing the result and correcting abnormalities. Although our
study showed that in-hospital death was associated with
inadequate management of hypokalemia on medical record
review, we did not demonstrate that lack of correc-
tion of hypokalemia was associated with mortality.

Pine and colleagues10 have recently shown that the
addition of laboratory data, including serum potassium
test results, to administrative data improves the ability
to predict in-hospital mortality and between-hospital com-
parisons. When laboratory values were combined with
secondary diagnoses available on the administrative data
set, they improved the prediction of mortality for 3 pri-
mary diagnoses (acute myocardial infarction, congestive
heart failure, and pneumonia) such that additional
clinical data obtained by data extraction from medical
records contributed little to predictive power. Further-

### Table 3. Clinical Management of Severe Hypokalemia as Determined by the Medical Record Compared With Outcomes Derived From the Laboratory Computer System in a Random Sample of 100 Patients

<table>
<thead>
<tr>
<th>Management of Severe Hypokalemia per Medical Record (Gold Standard)</th>
<th>Computer-Derived Measure</th>
<th>Likelihood Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Receiving Inappropriate or No Potassium Supplementation (n = 24)</td>
<td>No. Receiving Appropriate Potassium Supplementation (n = 76)</td>
<td>Sensitivity, %</td>
</tr>
<tr>
<td>No subsequent test performed</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Serum potassium level never corrected</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Last serum potassium test result abnormal</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>Died in the hospital</td>
<td>8</td>
<td>16</td>
</tr>
</tbody>
</table>

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more, Mozes and colleagues\textsuperscript{20} have shown that low potassium test results combined with age are powerful predictors of length of stay. The use of laboratory data to augment predictive ability can only be efficient when the data are computerized—examining medical records to abstract laboratory data is fraught with errors, omissions, and prohibitive costs.\textsuperscript{21}

There are several advantages of using computerized laboratory data in a clinical audit. First, data entry is automated with no delay between obtaining the results and reporting. Second, data accuracy (reliability and validity) is likely to be high since there are fewer coding errors (because of automation) and because the built-in quality assurance mechanisms that are in place in the laboratory, such as frequent recalibration, reperformance of tests with abnormal results, and participation in external quality assurance programs in which blind samples are tested, tend to minimize problems of validity. Third, the computerized database provides a complete data set for case finding. As Iezoni\textsuperscript{18(p672)} noted, “by knowing actual hematocrits, we could decide ourselves if anemia is present” and not have to rely on diagnostic codes. In our case, without the use of the laboratory database, an audit on the management of hypokalemia would have been impossible, since only 1.7% of cases ascertained through the database received a diagnostic code for hypokalemia in the administrative database. Unlike clinical conditions such as congestive heart failure or habits such as tobacco use, which are frequently missing from administrative and insurance claims databases,\textsuperscript{22,23} all measured laboratory results are included in the laboratory database. Finally, as our audit has shown, the pattern of the test results themselves, as summarized from the computerized database, highly reflects the clinical management of the electrolyte disorders (as obtained from the medical record). Our results suggest that a computerized audit for the management of electrolyte disorders could be incorporated into the routine quality assurance procedures in the hospital. Since the time available to perform assessments of clinical performance is a major constraint,\textsuperscript{24} an audit technique that streamlines the ability to collect and analyze available data is sorely needed.

Laboratory alerting systems that monitor decreasing potassium levels and other laboratory abnormalities have been found to improve the quality of care\textsuperscript{19} and to decrease the rate of adverse drug reactions\textsuperscript{25} and the length of stay.\textsuperscript{13} Further studies to investigate the impact of such laboratory audit systems on the management of hypokalemia and other electrolyte disorders in hospitalized patients should be undertaken.

Accepted for publication November 21, 2000.

We thank Michael Mayer, MD, for his input and cooperation; and the manuscript’s reviewers for their constructive comments.

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REFERENCES