# Laboratory Reporting of the International Normalized Ratio

## Progress and Problems

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• ***Context.*—The international normalized ratio (INR) is widely used to monitor oral anticoagulation and to evaluate patients with coagulation disorders.**

***Objective.*—To examine the variability of the performance and reporting of the INR and to evaluate laboratory calculation of the INR.**

***Design.*—Between 1993 and 2003, laboratories participating in proficiency testing were surveyed. Participants provided the international sensitivity index and the mean normal prothrombin time used to calculate the INR. The INR was calculated from the data provided and compared with the INR reported to determine if the calculation was correct.**

***Results.*—Survey data regarding the INR collected between 1993 and 2003 demonstrate an improvement in reporting, using appropriate anticoagulant, using lower international sensitivity index reagents, and matching international sensitivity index and prothrombin time method. The all-method coefficient of variation of the INR improved from 18% to 5.8%. Among 3813 laboratories studied in 2002 and 2003, 4.1% miscalculated INR. Of 29 laboratories that reported investigation of the INR miscalculation, 11 (38%) reported correcting an INR that was being reported in patient results and that this error was corrected as a result of the study. Since beginning grading of the INR calculation, miscalculation of the INR has fallen to less than 1%.**

***Conclusions.*—Recommendations for change in laboratory practice made by consensus conferences are implemented during the course of many years. Difficulty calculating the INR was documented, and both the calculation and the variability in the reporting of the INR showed improvement. Proficiency testing, when closely evaluated and acted on, can have a direct impact on the quality of patient care.**

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The prothrombin time (PT) has been used to monitor oral anticoagulant therapy since the introduction of warfarin in 1941.[1] Initially, the reagents used to perform the test were prepared in each laboratory causing wide variability of results. In the latter part of the 1960s, commercially prepared reagents and instrumentation for detecting the end point of the PT grew in popularity and reduced the degree of variability to some extent. However, manufacturers' reagents differed from one another, and individual lot numbers from a given manufacturer showed similar variability.[2] The importance of both the degree and the nature of this variability were called to attention by Poller and Taberner[3] in an epidemiologic study in which it was demonstrated that both the rate of hemorrhagic complications and the dosage of Coumadin varied in different regions of the world. This variability was ascribed to the different sensitivities of the thromboplastin reagents used to perform the PT. As a result, they proposed the international normalized ratio (INR) procedure for mathematically adjusting the PT to be equivalent across many different reagent sensitivities.[4] Acceptance of the INR in Europe and other regions of the world was rapid, being nearly universally used by the end of the 1980s. In contrast, acceptance in the United States was slower, lagging behind by nearly a decade. During the course of the last decade, there have been many recommendations about the performance of the PT (INR) regarding the concentration of the citrate anticoagulant, the sensitivity of the reagent used for performing the test, methods of reporting, and others.[5–8]

Two studies that were carried out in conjunction with the proficiency testing program for the PT (INR) admin-

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| Table 1. Laboratory Participants, International Normalized Ratio (INR), Coefficient of Variation (CV), and Overall Survey Response Rate, 1992 Through 2005 | | | | | | |
|---|---|---|---|---|---|---|
| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
| No. of laboratories | 1022 | 661 | 866 | 759 | 674 | 778 |
| Specimen INR | 3.11 | 3.72 | 3.45 | 2.85 | 2.75 | 2.67 |
| CV for INR | 18.33 | 10.75 | 13.04 | 8.07 | 8.00 | 12.73 |

istered by the College of American Pathologists (CAP) and overseen by the CAP Coagulation Resource Committee (CoRC) are described. In the first study, to determine how coagulation practices among US laboratories had changed over time, a series of questions were submitted to participants in the comprehensive coagulation proficiency testing program between 1993 and 2003. The survey was comprehensive; we report on the data over time to 6 key coagulation practices, providing longitudinal information on changes that have occurred in performance of the test, acceptance of the INR, and improvement in the interlaboratory variability. Because of the observation of a lower rate of consensus among laboratories reporting the INR compared with the rate of consensus when reporting the PT in seconds, suggesting that some laboratories were not accurately calculating the INR, a second study of the ability of laboratories to correctly calculate the INR was investigated.

## METHODS

### Study 1—Longitudinal Change in Coagulation Practice

Beginning in the fall of 1993, participants in the comprehensive coagulation survey were asked to respond to more than 30 questions regarding laboratory practices in the performance of the PT. This questionnaire was submitted in the fall, annually through the year 2000, and again in the fall of 2003. Participants were requested to respond to each question in the questionnaire. Items in the questionnaire reported here include whether the INR is reported, method of reporting the INR, concentration of citrate anticoagulant used in specimen collection, the assignment of the international sensitivity index (ISI) to the method, and the upper limit of the reportable range of the INR. The data were then tabulated and examined for change over time. In addition, in early 2005, participants were asked to submit their reportable range for the INR.

### Change in the Coefficient of Variation of the INRs of Proficiency Testing Samples Over Time

As a general measure of the improvement of the performance of the INR among the participants in the proficiency testing, the coefficient of variation (CV) was measured for all methods beginning in 1992 when participants were first asked to report the INR. For each year, a lyophilized sample prepared from patients receiving oral anticoagulant therapy (INR range, 2.67–3.89) was submitted to participant laboratories (range, 635–1022 laboratories). From 1992 until 2001, the INR was not graded, but results were reported back to participants. Beginning in the year 2002, the INR was graded as part of the assessment of participant performance and as a requirement for accreditation.

### Study 2—Evaluation of the Accuracy of the INR Calculation

In every proficiency testing challenge, each laboratory reported the PT result in seconds and INR on 5 specimens. To determine if individual participants were correctly calculating the INR, the laboratory was requested to provide the ISI of the thromboplastin and the mean normal PT used for the calculation. From the information provided, the CAP calculated the INR of each specimen for each laboratory. The INR reported by the laboratory in the proficiency testing challenge was then compared with the INR calculated by the CAP. This study was done on 2 separate occasions, initially in the summer of 2002 (CG 2002-B) and subsequently in the spring of 2003 (CG 2003-A). Using the data from all 5 specimens, calculation errors were determined. Those laboratories reporting only a single miscalculated INR or who reported a mean PT or ISI that was obviously incorrect (eg, if an ISI of 12 were reported instead of 1.2) were judged not to have a systematic calculation error and were excluded from further analysis. Thus, 208 of 365 laboratories were excluded, leaving 157 laboratories for further study. These were subjected to statistical evaluation to determine the severity of the calculation error, graded as moderate or high, weighing both the number of errors that occurred among the 5 specimens and the magnitude of the error reported. All of the laboratories with calculation errors rated high based on this statistical evaluation were then contacted, informed of the possible error, and requested to report the results of their investigation of the problem back to the CoRC. The reported data were tabulated for further analysis.

Because of the result of this study, the CAP/CoRC began grading the INR calculation in 2004. Every participant laboratory was required to provide the ISI and the mean normal PT used in the calculation of the INR. The CAP calculated the INR and comparison was made to all 5 INR values reported. Variation of the result by 10% or more in 3 or more results was considered a failure, requiring corrective action by the participant.

### Statistical Analysis

The participant data surveys were screened for error prior to statistical analysis. Preliminary data were analyzed using graphical methods wherever applicable to facilitate inspection and interpretation of the data. Influential observations were identified and checked for accuracy. Data error because of data entry oversight was appropriately corrected. In addition, data were summarized using appropriate descriptive statistics (eg, mean and standard deviation [SD] for continuous variables; count and frequency for categorical variables).

To access the overall laboratory performance over time, CV for the INR among survey participants was calculated from 1993 to 2003. Prior to calculation of CV, data were subjected to a 2-pass, 3-SD test for outliers. Those data points that were greater than 3 SD from their peer method mean on the first pass were removed. The procedure was then repeated.

The error rate was further computed by comparing the INR value reported by the laboratory in the proficiency testing challenge to the INR value calculated by the CAP. Error rates between 2003 and 2005 were compared to determine change over time. Significance tests were conducted using $z$ statistics with an $\alpha$ level of .05. All statistical analyses were performed using SAS 9.1 statistical software (SAS Inc, Cary, NC).

## RESULTS

Table 1 shows the change in CV of the INRs of proficiency testing from 1993 to 2003. The rate of response to the questions varied from question to question and from year to year. The lowest rate of response occurred with question 4 in the year 1995 (86.7%); the highest rate of response occurred with question 2 in the year 1996 (99.2%). Data from the responses to the questions are presented in Figure 1, A through D.

| Table 1. Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** |
| 734 | 736 | 635 | 697 | 755 | 791 | 789 | 789 |
| 3.01 | 3.12 | 3.89 | 3.18 | 2.71 | 2.34 | 2.73 | 2.41 |
| 8.31 | 8.97 | 9.51 | 7.55 | 7.01 | 6.41 | 5.86 | 5.81 |

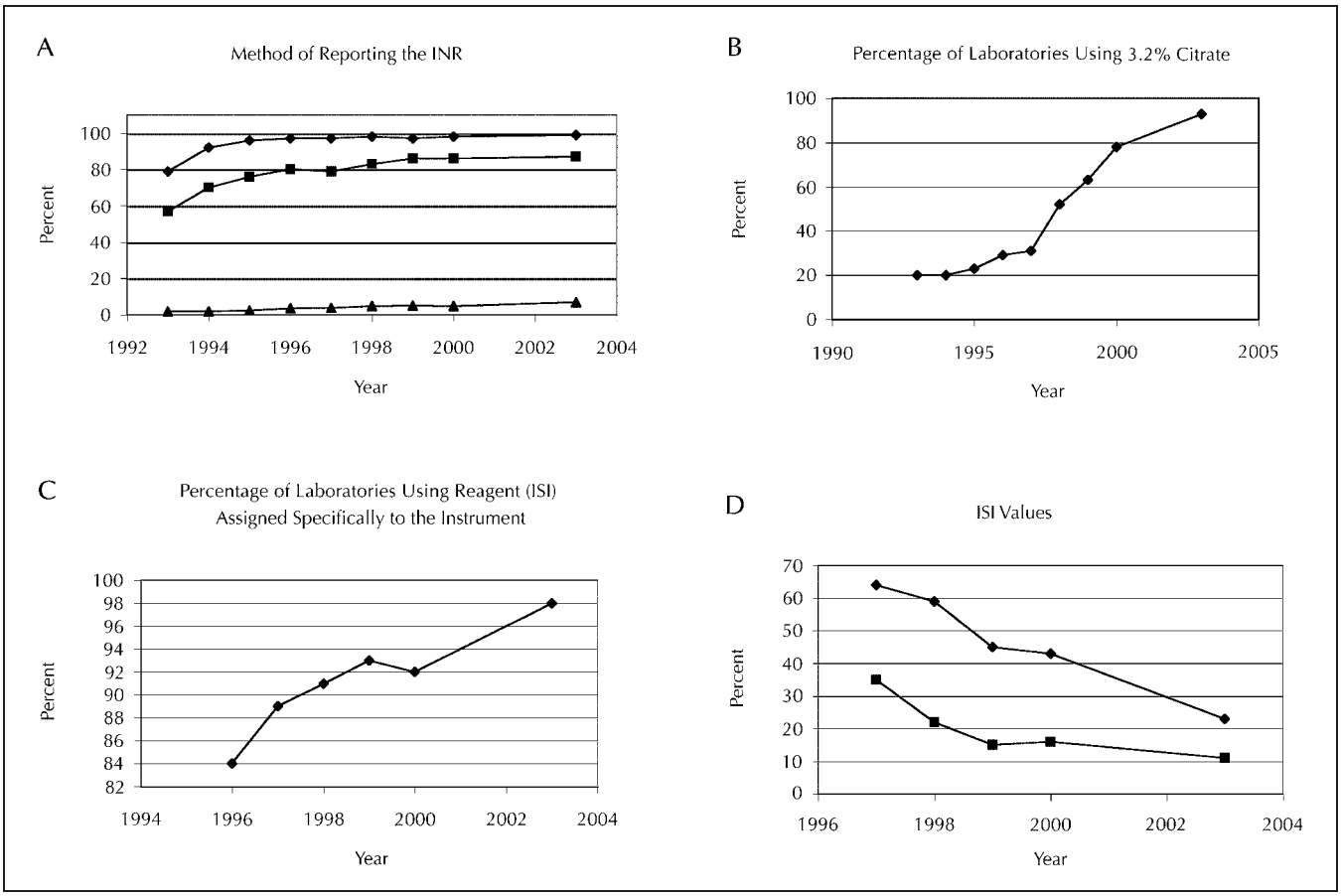



**Figure 1.** *Longitudinal change in coagulation testing practice. The responses to survey questions are presented. A, The total number of laboratories reporting the international normalized ratio (INR) (diamonds) and the change in reporting practices: reporting both the prothrombin time in seconds and INR (boxes) and reporting INR alone (triangles) over time. B, The change to the use of 3.2% (0.109M) sodium citrate anticoagulation for collection of the specimen for prothrombin time/INR testing. C, The reported change in laboratories using a thromboplastin reagent with an international sensitivity index (ISI) matched to the instrument. D, The change in the reported value for the ISI as the percentage of laboratories using an ISI above 2.0 (boxes) or above 1.7 (diamonds).*

### Reporting of the INR

At the time the questionnaire began in 1993, 79% of laboratories were reporting the INR. By the end of 2003, more than 98% of laboratories were reporting the INR and more than 80% reported both the PT in seconds and the INR (Figure 1, A). A small proportion of laboratories (7.0%) in the United States reported the INR alone, without the PT in seconds.

### The Use of 3.2% Citrate

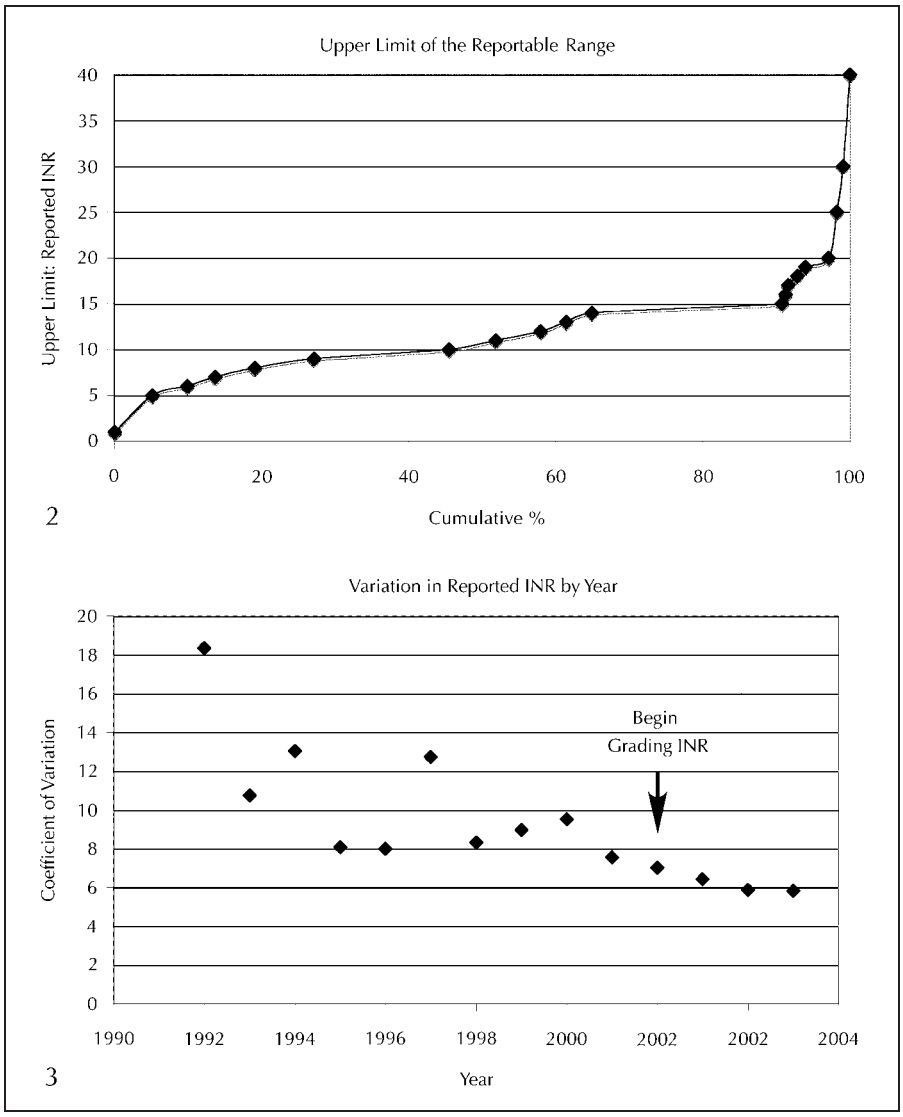
Consensus conferences in 1997[7,8] recommended that the citrate concentration used for the anticoagulation of specimens be reduced from 3.8% (0.129M) to 3.2% (0.109M). Since these recommendations were made, there has been a slow but steady growth in the use of 3.2% citrate reaching a level of 92% in 2003 (Figure 1, B). Prior to the consensus conferences of 1997, the use of 3.2% citrate was quite stable.

### Matching of the Reagent ISI to the Instrument Used and the Method

Laboratories are gaining a greater recognition of the importance of matching the reagent, the instrument, and the ISI. This change also is reflected in a change occurring in the market place. Beginning in 1996, data regarding the selection of a reagent whose ISI was specific for the instrument were collected. By the end of 2003, the matching of reagent and instrument had reached 98% (Figure 1, C). When the CoRC first began gathering information on methods (instrument/reagent combinations for the PT) in 1981, there were 35 different instrument/reagent combinations being reported. The number of instrument/re-

**Figure 2.** *Upper limit of the reportable range for the international normalized ratio (INR). Laboratories (n = 2346) reported the upper limit of the reportable range for the INR. Values were ranked by INR value and the cumulative summation plotted.*

**Figure 3.** *Variation in reported international normalized ratio (INR) by year. Coefficient of variation (CV) was calculated from all INR methods reported each year. Among CV reports for each year, the data used for the calculation included a range from 635 to 1022 and a range of the mean INR from 2.67 to 3.89. Grading of the INR proficiency testing began in 2002 (arrow).*




agent combinations reported in the surveys increased rapidly, reaching a peak of 305 different combinations in 1997. However, the number of instrument/reagent combinations fell to 152 by 2003.

### Reagent ISI

In 1997, consensus conferences of the CAP and the American College of Chest Physicians recommended that the ISI of the reagent used for the performance of the INR should be between 0.9 and 1.7. At the time, many laboratories in the United States were using reagents with ISIs above 2.0 (insensitive reagents) with a substantial proportion above 2.5. Over time, more laboratories moved into compliance with these consensus conferences recommendations; however, in 2003, there were still 22% of laboratories using reagents with an ISI above 1.7 and 10% of laboratories using reagents with an ISI above 2.0 (Figure 1, D).

### Maximum Reportable INR

Current American College of Chest Physicians guidelines include decision points for the management of excess anticoagulation at INRs of 5.0 and 9.0.[8] The cumulative summation of the maximum reportable INR is shown in Figure 2. The maximum reportable INR is less than 9 in 20% of laboratories.

### Reduction in the Variation of the Reporting of the INR

In 1992, when the CoRC first began collecting information on the reporting of the INR, the CV for the results on the same specimen for all methods was more than 18%. The CAP/CoRC began grading the INR results in 2002. Figure 3 demonstrates graphically the reduction in the CV that has occurred over time with the CV in 2005 being 5.8% (ranges: *n*, 635–1022; mean INR, 2.34–3.89; Table 1). During the period of the study, there is continued improvement in the CV to a plateau with only slight subsequent improvement after 2001.

### Participant Calculation of the INR

The results of the assessment of participant calculation of the INR are presented in Table 2. Participation in these studies was voluntary. Of 7565 participants reporting the INR in these 2 challenges, 3813 (50.4%) reported data permitting CAP calculation of the INR. Errors for 208 of 365 laboratories were judged not to have a systematic calcu-

| Table 2. International Normalized Ratio (INR) Calculation Errors, 2002 and 2003 | | | |
|---|---|---|---|
| | 2002 | 2003 | Total |
| Total No. of laboratories submitting data* | 1843 | 1970 | 3813 |
| Total laboratories with INR calculation errors, No. (%) | 182 (100) | 183 (100) | 365 (100) |
| Errors not related to calculation, No. (%) | | | |
| Obviously incorrect data† for mean PT‡ or ISI | 23 (12.7) | 14 (7.7) | 37 (10.1) |
| Incorrect reported INR | 5 (2.8) | 3 (1.6) | 8 (2.2) |
| Single random error—4 of 5 calculations correct | 77 (42.3) | 86 (47.0) | 163 (44.7) |
| Errors related to calculation by severity, No. (%) | | | |
| Moderate (2 or 3 calculation errors) | 29 (15.9) | 11 (6.0) | 40 (11.0) |
| High (4 or 5 calculation errors) | 48 (26.4) | 69 (37.7) | 117 (32.1) |
| Total laboratories reporting multiple incorrect results suggestive of systematic calculation error, No. (%) | 77 (4.2) | 80 (4.0) | 157 (4.1) |
| Percent (No./total No.) with significant INR calculation error | 4.2 (77/1843) | 4.0 (80/1970) | 4.1 (157/3813) |

* Not all participants submitted international sensitivity index (ISI) and mean normal prothrombin time (PT) data.

† Example of obviously incorrect data or incorrect INR would be a misplaced decimal (reporting an ISI of 12.7 rather than 1.27 or an INR of 21 rather than 2.1).

‡ Mean PT indicates geometric mean of the reference range of the prothrombin time in seconds.

| Table 3. Laboratories Failing the International Normalized Ratio (INR) Calculation | |
|---|---|
| Year | Laboratories With Calculation Errors, % |
| 2002 | 4.2 |
| 2003 | 4.0 |
| (Grading of the INR calculation began in 2004) | |
| 2004 | 1.3 |
| 2005 | 0.7 |

lation error. The remainder, 157 (43.0% of those with errors detected; 4.1% of the total participants reporting sufficient data) had significant, systematic errors in the calculation of the INR.

Of the 182 laboratories that were identified with problems in 2002, 91 (50%) submitted data in 2003. Among these laboratories, 20 were identified with a problem in 2003, of which 12 had calculation errors. Thus, 12 (15%) of the 80 serious calculation errors identified in 2003 were from laboratories that also reported errors in 2002. Therefore, some laboratories continued to have calculation errors, and others who did not report errors in the prior year had developed errors in the following year.

Each of the participant laboratories with an error score of ''high'' (4 or more calculation errors in 5 specimens) was sent a letter explaining the error and encouraging the laboratory to examine the data and investigate the method for calculation of the INR. They were requested to report the results of this investigation to the CoRC. Of 117 laboratories contacted, 29 (24.8%) reported the results of their investigation. Thirteen laboratories were reporting patient results correctly but reported incorrect data to the CAP. Five laboratories provided incomplete information in their report back to the CAP. However, 11 laboratories reported a change in their method of reporting the INR, leading to improved patient care.

### Grading of the INR Calculation

After beginning grading of the calculation in 2004, fewer laboratories had calculation errors (Table 3). Based on the data reported in the surveys, there was a statistically significant improvement in the calculation error rate ($P < .001$) from 4.2% to 0.7% between 2002 and 2005.

## COMMENT

The development and implementation of the INR has clearly improved the clinical monitoring of oral anticoagulation in patients and enhanced the ability to communicate effectively in the literature regarding management of oral anticoagulation. With these positive developments have come new demands on the laboratory. To further optimize the uniformity in the data reported for patient care, other improvements such as the concentration of anticoagulant in the specimen and the characteristics of the reagent itself have been introduced during the past 2 decades. Despite the recommendation of more than one consensus conference, the data reported in this study indicate that it has taken 6 years or more to reach substantial compliance with these recommendations. In 2003, there were still more than 20% of laboratories using reagents with an ISI above 1.7 and more than 10% using reagents with ISI above 2.0. The compliance with the recommendation to reduce citrate concentration steadily increased to the point that more than 90% of laboratories are now using the lower concentration. Data are not available regarding the reason that laboratories have been slow adopting recommended changes. One may speculate that changing methods requires new method validation, a process that is not easy for smaller laboratories. In addition, many clinicians use the PT in seconds to guide fresh frozen plasma therapy in the bleeding patient. Substantial increase in the sensitivity of the reagent may have a significant impact on the appropriate threshold for fresh frozen plasma transfusion and lead to inappropriate transfusion as clinicians adjust to the change.

The clinical use of the INR was rapidly adopted in Europe; however, by 1992, only 80% of laboratories in the United States were reporting the INR. By 2003, nearly all laboratories (but not every laboratory) were reporting the INR. More than 90% report both the INR and the PT in seconds, whereas only 7% report the INR alone. There continues to be debate about the use of the INR alone. It is true that the application of the INR was developed originally for the monitoring of oral anticoagulation, and there are data to indicate that the use of the INR in other clinical settings does not have the same uniformity of results between methods as one can see in patients who are taking oral anticoagulants. Because the INR is merely a calcula-

tion from the PT in seconds, this also means that the PT in seconds will have a similar variability among methods in these clinical settings. In other countries, the use of the INR alone as a method of reporting the PT is more common with nearly 100% use in Sweden. Of the laboratories in some Canadian provinces, 85% report the INR alone according to an e-mail communication from A. Raby, MLT, ART (November 2006). The reason for the variation in practice is not clear. Reluctance to change practice is a likely reason in many cases. Another issue is that the Clinical Laboratory Improvement Amendments of 1988 regulations require that the proficiency testing for the PT be reported in seconds only not the INR. The Center for Medicare and Medicaid Services has not addressed this issue. This continues to be a much-debated topic about which there is no uniform opinion.

In order for the INR to be used effectively, the ISI of the reagent needs to be developed for the specific instrument with which it is used.[7] Adoption of this principle has continually improved, rising from 84% in 1996 (the time of the first question regarding this practice) to more than 90% in 2003. In addition, this has also contributed to a reduction in the use of reagents and instruments that are prepared by different manufacturers. Since the peak in 1997 of 305 different methods reported to the CAP for doing the PT, this figure fell in half to 152 by 2003. Reductions may be explained based on (1) the importance of matching the reagent to the instrument regarding the ISI, (2) the more common practice of laboratories acquiring instrumentation through reagent-rental or lease agreements that are linked to a reagent purchase, and (3) consolidation in the diagnostic industry and among health care systems. Recently, studies have proposed local determination of the ISI using calibrator plasmas of known INR.[9–11] The Clinical Laboratory Standards Institute has published a guideline recommending local validation of and, if necessary, calibration of the ISI. This requires a set of plasma standards of known INR. This practice is in use in other countries; however, sets of calibration plasmas have not been approved as yet by the Food and Drug Administration and are not readily available in the United States. Development of local validation and calibration of the ISI should lead to improvement in concordance of the INR among laboratories.

Consensus conferences dating back to the mid-1990s have recommended clinical intervention in patients who have a markedly elevated INR because of excess oral anticoagulation.[7,8] Currently, the thresholds for these interventions occur at an INR of 5.0 and an INR of 9.0. It is interesting to know that the upper limit of the reportable range for the INR in laboratories is below a level of 9.0 in 20% of laboratories and below 5.0 in 5%. In those clinical settings in which the laboratory has an upper limit of the reportable range below these recommended therapeutic intervention levels, clinical management of patients may be more difficult. In addition, many laboratories report INRs as high as 20.0 or above. Determination of the upper limit of the reportable range of a test is dependent on the local application of a given method; however, because of the sensitivity of reagents that are being used, results with these extremely high levels show poor reproducibility and high discordance. The practice of reporting INRs beyond 20 is discouraged and above 10 is questioned.

Participants in the CAP coagulation surveys have been reporting information on the INR since 1992. Beginning in 2002, the CAP began grading the INR proficiency tests. In the course of 11 years, the overall intermethod CV for the INR has dropped remarkably from 18% to a level slightly below 6%. This improvement in CV is likely a reflection of many factors including, but not limited to, improvement in ISI assignment and increased awareness of laboratories to the importance of the INR.

Accreditation of a laboratory by the CAP requires that the laboratory periodically document the accuracy of the calculation of the INR. Despite this auditable requirement, the 2002 and 2003 studies reported here show that more than 4% of laboratories were having difficulty with appropriate calculation of the INR. In the majority of cases, the errors in calculation were in the use of the appropriate geometric mean of the reference range of the PT or of the ISI for the reagent/instrument combination. Observations during inspection of laboratories made by us have uncovered instances in which the laboratories did not know where the INR calculation occurred in their information systems (eg, if a laboratory reports an ISI of 1.1 in their instrument but did not realize that the INR is calculated in the laboratory information system [LIS] where the ISI is recorded as 1.4). The options include having the calculation of the INR performed by the instrument, with the INR transmitted to the LIS and patient record, or having the data for the mean PT and the ISI in the LIS, with the LIS calculating the INR based on the PT in seconds transmitted from the instrument. Failure to ensure that appropriate updates to the ISI and mean normal PT are made at either the instrument or the LIS level may result in erroneous INRs being reported to the medical record.

Some laboratories have had difficulty in appropriately setting up the formula for calculation of the INR. The correct formula is as follows:

$$\mathrm{INR} = \left(\frac{\text{Patient PT}}{\text{Mean Normal PT}}\right)^{\mathrm{ISI}}.$$

The management of the parenthesis in this formula is extremely important. The following 2 errors in the structure of the formula were being used in laboratories:

Error 1:

$$\mathrm{INR} = \frac{\text{Patient PT}^{\mathrm{ISI}}}{\text{Mean Normal PT}}$$

Error 2:

$$\mathrm{INR} = \text{Patient PT}/\text{Mean Normal PT}^{\mathrm{ISI}}.$$

In the error 1 formula, the absence of the parentheses raises the power of only the patient's PT to the power of the ISI rather than the PT ratio, and the error 2 formula, structured in a more linear fashion without the parentheses, causes only the denominator (the mean PT) to be raised to the power of the ISI.

The final error that was detected in 1 laboratory was multiplying the PT ratio by the ISI rather than raising the PT ratio to the power of the ISI as shown in the following:

Error 3:

$$\mathrm{INR} = \left(\frac{\text{Patient PT}}{\text{Mean Normal PT}}\right) \times \mathrm{ISI}.$$

Regardless of the nature of the error in the laboratory, the result will be reporting an incorrect INR, placing patients at risk for bleeding or thrombotic complications.

Among those laboratories that had severe calculation er-

rors, a letter was sent to each laboratory pointing out the error, the most likely reason for the error, and recommendations to check the entire method for calculation and reporting of the INR to ensure that patient results were correct. Of the 117 laboratories to which letters were sent, 29 responded with the requested outcome of their investigation. Among the 29 laboratories that reported the results of their investigations, 11 (38%) discovered that they were reporting an incorrect INR in patient results and that they corrected that error as a result of the study. One can do no more than speculate regarding the 88 laboratories that, as a result of the letter, would certainly have conducted some investigation but did not report the results of that investigation back to the CAP. Applying the percentage of those who did correct a patient reporting error among those who responded to this population would almost certainly have some bias; however, it is reasonable to assume that there were other laboratories in which patient reporting errors were detected and corrected. These findings provide an important example of the way careful analysis of the data reported in proficiency testing can directly impact the quality of patient care.

Beginning in 2004, laboratories were required to provide ISI and mean PT to the CAP for each of their proficiency testing challenges, and their calculation of the INR was graded. Results of that exercise indicate that in contrast to the 4% error rate in the original 2 studies, current error rates are at 1% or less. This reduction in the number of laboratory errors in calculation of the INR is encouraging; however, it does mean that there are still as many as 40 to 50 participating laboratories that are having difficulty with the INR calculation. This is an area in laboratory practice that should be able to function essentially error free. Continued effort in education and regulation to bring this issue under even better control to maximize safety for patients receiving oral anticoagulation is certainly needed.

In summary, data from the CAP proficiency surveys demonstrate gradual alignment of laboratory practice with recommendations from consensus conferences and a corresponding improvement in performance of the INR for monitoring oral anticoagulant therapy. Laboratories need to remain alert to potential sources of error in the calculation of the INR and future consensus conference recommendations. Rapid adaptation of such recommendations should translate into improved clinical outcomes for patients on oral anticoagulant therapy.

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