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# An assessment of overutilization and underutilization of laboratory tests by expert physicians in the evaluation of patients for bleeding and thrombotic disorders in clinical context and in real time

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## Abstract

**Background:** Diagnostic error is extremely common in the USA and likely around the world. A major reason for the diagnostic error is both the overutilization and the underutilization of laboratory tests. Using a panel of two to four experts in coagulation, test selection was reviewed in clinical context and in real time, and consensus determinations were made to derive conclusions about the extent of overutilization and underutilization.

**Methods:** Two hundred cases of patients being evaluated for bleeding or thrombotic issues were presented at each daily meeting of the diagnostic management team, and a review of each case for appropriate utilization of tests was completed.

**Results:** Two hundred randomly selected cases revealed 77.5% diagnostic errors (155 cases). Sixteen percent were associated with overutilization of laboratory tests, 44% were associated with underutilization, and 17.5% were associated with both. The annual cost burden estimated for overutilization alone in one institution of 450 beds was on the order of \$20,000. The cost burden for the delay in diagnosis or the misdiagnosis in cases with underutilization is orders of magnitude greater (\$200,000 or more), but it is impossible to determine the cost of a misdiagnosis in an individual case because it can produce many different clinical outcomes.

**Conclusions:** This was a rare opportunity for experts in a given field to review cases in real time and in

clinical context and provide immediately a consensus answer about test utilization. The results of this study show errors in test selection in nearly 75% of the cases evaluated.

**Keywords:** coagulation; laboratory test selection; overutilization; underutilization.

## Introduction

In September, 2015, the National Academy of Medicine, formerly the Institute of Medicine, issued a report on diagnostic error in America. The principal conclusion is that every adult American experiences at least one diagnostic error in a lifetime [1]. In fact, other reports and commentaries suggest that the number of diagnostic errors experienced by an individual American adult is far greater than one.

One of the major contributing factors to diagnostic error is the failure to order the correct diagnostic tests. It has long been known that overutilization of laboratory tests is a common and costly problem [2–5]. More recently, underutilization of laboratory tests, which can occur in the same patient as overutilization, is a major contributing factor in the delay in diagnosis or generating an incorrect diagnosis [5]. The problem with identifying the correct tests has many root causes, but currently the biggest challenge is that health care providers are simply not aware of what they do not know about the ability of lab test results to provide a correct diagnosis.

There are many individuals who claim that there is overutilization or underutilization of particular laboratory tests. These articles are usually written by an individual who has an opinion about overutilization or underutilization, but independent of the clinical context. It is very difficult to make sweeping conclusions about the overutilization, for example, of testing for hypercoagulability. It is certainly indicated in someone with a strong family

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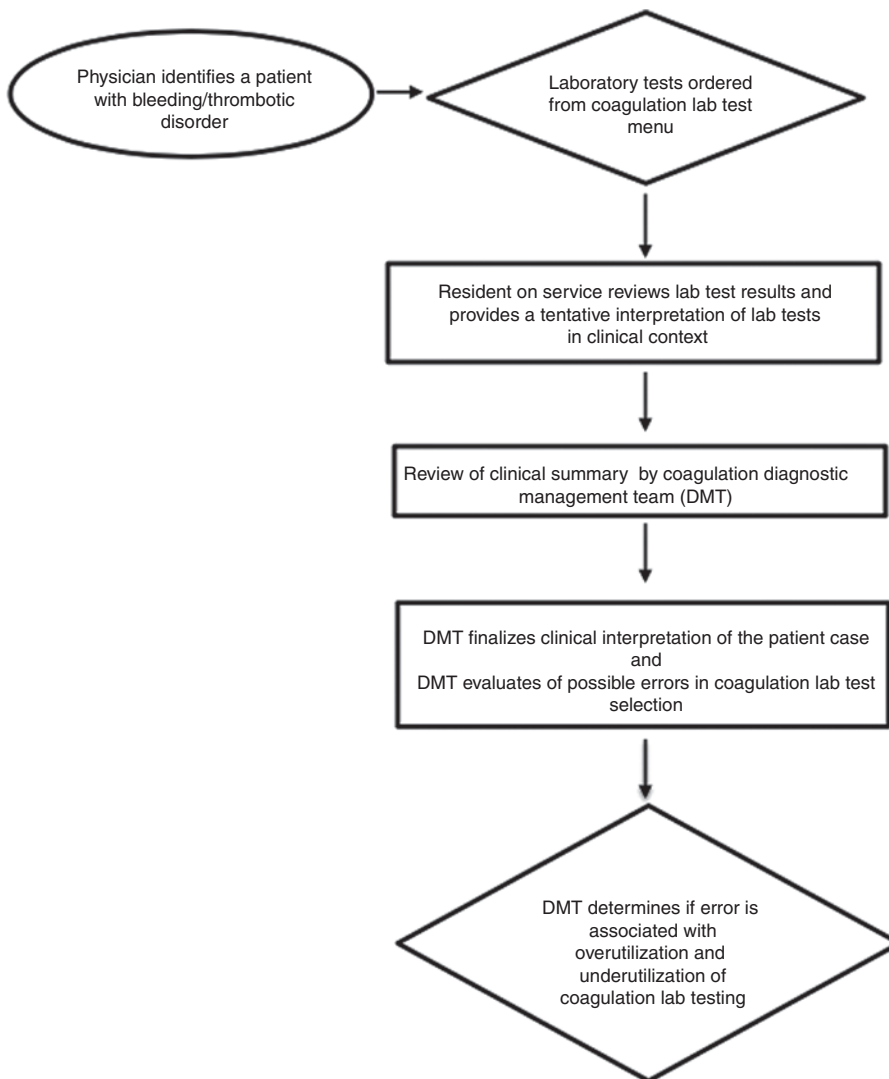
history of venous thrombosis, and this may be lost as broad conclusions about utility of tests for hypercoagulability are advanced.

This study presented the rare opportunity to have multiple experts in a specific field, diagnostic coagulation, to hear the presentation of patients who are being evaluated for bleeding or thrombotic disorders, and have the ability to provide an opinion about overutilization or underutilization on a case-by-case basis in real time. In addition, many cases were evaluated by this group, allowing a large number of cases to be screened for overutilization and underutilization of coagulation laboratory tests. The results of this study indicate that experts in coagulation hearing cases in clinical context found that overutilization and underutilization of laboratory tests are extremely common problems. Importantly,

underutilization is a common cause for delayed or inaccurate diagnosis.

## Materials and methods

This study set out to determine the number of errors in test selection for patients being evaluated for active bleeding or thrombosis or risk for bleeding or thrombosis. The results reflect the test results from 200 randomly selected patients in meetings held daily between August 2015, and February 2016, at an academic medical center. The institution has an integrated and well-established electronic health record and has multiple hospitals and many outpatient clinics for which care is provided. The patients for whom care is provided are ethnically and socioeconomically diverse. The main hospital included 310 patient rooms inclusive of 60 intensive care unit beds. Comprehensive care is provided annually to approximately 26,000 inpatients and in 750,000 outpatient visits [6].



**Figure 1:** Diagnostic error evaluation by coagulation DMT.

The daily meeting of experts from Monday through Friday is the work of the coagulation diagnostic management team (DMT). The residents in pathology review the clinical background for each patient, present this information along with the laboratory tests, which were performed related to coagulation, and provide a tentative interpretation of the laboratory test results. The attending physicians then shape the final interpretation and comment on the appropriateness of the laboratory tests, which were selected or omitted. Figure 1 shows the process for case review.

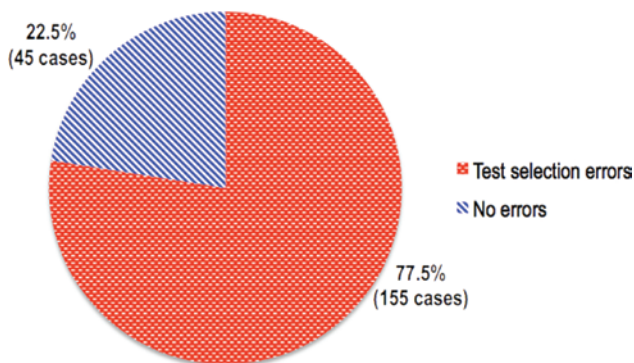
The study received expedited approval from the hospital Institutional Review Board.

The frequency of errors in test selection was quantitatively and statistically analyzed to assess overutilization and underutilization of tests relevant to coagulation.

It was impossible to determine the cost of the delayed diagnosis because the events resulting from the delay are highly variable. By contrast, it was possible to calculate the cost of the coagulation studies ordered that were unnecessary. Using list prices from two commercial laboratories, a quantitation of unnecessary expenditure from overutilization was also provided. Demographic data were obtained to determine whether errors were more likely to appear in one population of patients or another. Analysis of these data involved the use of the Fisher exact  $\chi^2$ -test (two-tailed) for the categorical variables of ethnicity and gender. All data were considered to be significant with a p-value of  $< 0.05$ . A t-test was used to compare the mean age of patients with and without errors.

## Results

Figure 2 shows the frequency of errors in test selection in the 200 cases, which were analyzed. There are no previous data for coagulation studies specifically to indicate the percentage of cases in which there was an issue of overutilization or underutilization [7–10]. We found 155 unique cases of diagnostic errors, and the error proportion rate of 77.5% of cases with error vs. cases with no error was statistically significant (95% confidence interval, 71.7%–83.3%;  $p < 0.0001$ ).



**Figure 2:** Frequency of diagnostic errors in the study of 200 cases. The error rate of 77.5% reflects cases with errors vs. cases with no errors and a 95% confidence interval of error proportion between 71.7% and 83.3% and p-value  $< 0.0001$ .

Table 1 shows the impact of ethnicity, gender, and age on the presence or absence of errors in laboratory test selection. With regard to ethnicity, the data show that the most errors were identified in individuals of African descent (error-no error ratio equals 11), followed by an error-no error ratio of 8 in patients of Hispanic ancestry, with errors in Caucasians showing the best error-no error ratio of 2.5. Overall, errors in test selection were significantly associated with ethnic origin of the patient ( $p = 0.012$ ). In addition, women being evaluated for bleeding or thrombotic disorders experienced more errors in test selection (error-no error ratio equals 5) than did men (error-no error ratio equals 2),  $p = 0.013$ . The mean age of patients being evaluated in this study for test selection errors showed that younger patients were found to have more errors than older patients (39.2 years vs. 46.8 years,  $p = 0.016$ ).

Table 2 shows the principal diagnosis associated with the patients who were evaluated. In this cluster of 200 patients, which were randomly selected for evaluation, 18% were being evaluated to determine their risk for fetal loss or to determine whether the patient qualified for a diagnosis of antiphospholipid syndrome. There were a host of other categories, which included deep vein thrombosis, postoperative bleeding, pulmonary embolism, and vaginal bleeding. The category listed as other includes more than 15 different causes, for example, hematemesis, Raynaud's syndrome, epistaxis, etc.

Table 3 shows the percent distribution of patients who experienced overutilization, underutilization, or both of laboratory tests in evaluations for bleeding or thrombosis. As noted earlier, the same patient may experience overutilization of one particular laboratory test, while other important laboratory tests were omitted, resulting in the dual classification of overutilization and underutilization in the same case. As shown in Table 3, 16% of patients were in the category of overutilization only, 44% of patients in underutilization only, and 17.5% of patients fell in the category for both.

Finally, the data in Table 4 show the charges from two commercial laboratories for overutilization of tests alone per the 200 cases in this study. In our 200 cases, the dollar value for overutilization was \$6054 per 200 cases with an annual cost burden estimated at \$18,162 because the cases analyzed represented approximately 33% of the annual number of cases.

## Discussion

Diagnostic error is a major problem in the USA, and a wide body of studies suggest that failures in the diagnostic

**Table 1:** Patient characteristics in hospital visits with and without diagnostic error.

Characteristic	Error (n=155)	No error (n=45)	Error-no error ratio	p-Value
Patient ethnicity, no. (%)				
Caucasian	96 (61.9)	38 (84.4)	2.5	
African American	33 (21.3)	3 (6.7)	11	
Hispanic	24 (15.5)	3 (6.7)	8	0.012
Asian/Pacific Islander	2 (1.3)	0 (0.0)	–	
Other/unknown	0 (0.0)	1 (2.2)	–	
Patient sex, no. (%)				
Female	110 (71.0)	23 (51.1)	5	0.013
Male	45 (29.0)	22 (48.9)	2	
Patient age, mean (SD)	39.2 (18.1)	46.8 (19.8)		0.016

**Table 2:** Principal diagnosis associated with cases reviewed.

Principal diagnosis	No. (%) of cases (n=200) <sup>a</sup>
Miscarriage/spontaneous abortion/antiphospholipid syndrome	36 (18.0)
End stage renal disease/kidney transplant candidate	23 (11.5)
Deep vein thrombosis (DVT)	20 (10.0)
Follow-up of routine medical check up/no chief symptom	18 (9.0)
Leg pain/swelling/hematoma	14 (7.0)
Systemic lupus erythematosus	13 (6.5)
Stroke	12 (6.0)
Multiorgan failure/excessive post-operative bleeding/hematemesis/Raynaud's phenomenon	12 (6.0)
Hemophilia A/hemophilia B	11 (5.5)
Pulmonary embolism (PE)	10 (5.0)
Easy bruising/suspected von Willebrand disease	9 (4.5)
Anxiety/chest pain/joint pain/shortness of breath	8 (4.0)
Heavy/irregular menorrhagia/vaginal bleeding	7 (3.5)
Hypertension	5 (2.5)
Other	20 (10.0)

<sup>a</sup>Because of overlapping characteristics, the total number exceeds 200.

**Table 3:** Overutilization vs. underutilization in the diagnostic errors identified for coagulation testing.

Factor	No. (%) of cases (n=200)
None	45 (22.5)
Overutilization of laboratory tests	32 (16.0)
Underutilization of laboratory tests	88 (44.0)
Over and underutilization of laboratory tests	35 (17.5)

process results in patient harm, including deaths, which prompted an investigation by the National Academy of Science. Studies involving errors in clinical laboratories have shown that mistakes have been identified in preanalytical, analytical, and postanalytical phases of laboratory testing [11–13]. Further studies confirmed that errors in the preanalytical phase of test selection account for up to 70% of all mistakes in laboratory diagnostics [14]. In

the last decade, the complexity of clinical laboratory tests has increased substantially, making it difficult for physicians to select the correct laboratory tests and to interpret the test results correctly [15]. The simultaneous advent of automated technologies that use a variety of techniques has complicated ordering and interpretation of test results [16, 17]. This increases the potential for error many fold, which gives rise to a high prevalence of mistakes in test ordering and result interpretation. There have only been a few studies that examined the frequency of errors in clinical laboratory test selection and evaluation of the errors [18]. Our study describes the results of a unique opportunity to review 200 cases in clinical context and real time by multiple experts in the field of coagulation and to derive conclusions about overutilization and underutilization of test selection.

We showed that the frequency of errors in test selection is associated specifically with coagulation laboratory

**Table 4:** Charges for overutilized tests from two commercial laboratories and analysis of cost burden per 200 cases.

Test	Charge: commercial lab 1	Charge: commercial lab 2	Average of commercial lab charge	No. of cases	Unnecessary cost, \$\$
Protein C (antigen)	20.15	52.85	36.5	28	1022
Protein S (antigen)	20.15	40	30.1	28	843
Factor VIII	24.45	51	37.7	10	377
vWF analysis	62	111	86.5	11	951.5
Homocysteine	20	56	38	6	228
MTHFR mutation	85	109	97	6	582
Factor V	25.40	100	62.7	6	376
Protein C (functional)	30	40	35	6	210
Protein S (functional)	45	52	48.5	6	291
Factor IX	39.20	66.40	52.8	3	158
Factor XI	51.50	66.40	59	3	177
Antithrombin	52	54	53	5	265
Factor II	45.80	55	50.4	2	101
ANA	10	20	15	2	30
DRVVT (mix/confirm)	35	16	25.5	2	51
Serotonin release assay	336	91	213.5	1	213.5
ADAMTS13	168	118	143	1	143
FDP	43.50	26.95	35.2	1	35
Total unnecessary cost from overutilized tests					6054

tests (Figure 2). The dramatic result of 77.5% of cases associated with a test selection error shows the magnitude of the problem at an academic medical center where experts are available to provide consultative advice regarding test selection and result interpretation. It is possible that test selection in patient evaluation for coagulation disorders is greater than it would be for other clinical disciplines. The data shown in Figure 2 only show the results for disorders related to bleeding and clotting.

Errors in test selection were dependent on ethnicity, age, and gender of the patient as shown in Table 1. Our data suggested that Caucasians were less likely to experience a test selection error than non-Caucasians. Our data also showed that older patients and men had fewer errors than younger patients and women. It is not clear why the difference in age of approximately seven years would result in a different error rate for test selection.

We were also able to report the principal diagnosis associated with every patient (Table 2). This information is vital for targeted interventions to decrease errors in test selection. There is a myriad of symptoms that the primary care physicians encountered in the present study, and how it affected the clinical reasoning and influenced the test ordering should be an area for further investigation.

Our studies showed the overutilization and underutilization of tests in coagulation testing associated with diagnostic errors (Table 3). There were multiple cases where both occurred (17.5%). Not included in this analysis are errors in

the interpretation of the coagulation test results. This information is highly relevant to a discussion of diagnostic error. However, it is very difficult to assess all the diagnostic and treatment decisions made by a health care provider for an individual patient after lab test results and interpretation are received [10, 13, 15, 18]. Certain assumptions could be made when a clear mistake was made by someone involved in the care of an individual patient. We identified cases of missed diagnosis of antiphospholipid syndrome, incorrect interpretation of PTT mixing studies, diagnoses of factor V deficiency when a patient was heterozygous or homozygous for factor V Leiden, and many areas in the management of anticoagulation therapy. From our assessment, it appears that errors in interpretation of test results occurred in at least 12% of the cases.

We show an estimate of financial burden on the health-care system and also the patients as a result of overutilization in Table 4. The actual number of dollars lost from overutilization are likely to be very small compared to the large wastage from errors in underutilization because underutilization errors lead to prolonged stay in the hospital from delayed diagnosis or misdiagnosis [19, 20]. If the dollars lost from underutilization and misinterpretation of test results were included, we speculate that the dollars lost from these mistakes would at least be an order of magnitude higher.

The data in this report represent testing in an academic medical center with approximately 450 beds and a recently initiated coagulation DMT. One of us (ML) has

worked in a much larger hospital with a long-standing DMT [21]. The number of cases in that hospital is 10 times the number seen in the hospital from this report. Thus, for very large academic medical centers, the dollars lost just in overutilization can range from our reported value of \$18,000 to the much larger number of \$220,000 annually.

There are several limitations of our study. The primary limitation of case study reviews is that we have to rely on data cataloged in the medical records, and many diagnostic errors might be missed as a result. There was no physician debriefing, which if performed soon after recognition and analysis of errors could be useful to understand the diagnostic errors. The study was limited to the selection of patients suffering from coagulation or thrombotic disorders and associated laboratory diagnostic errors, and not inclusive of all diagnostic errors. Approximation of financial cost burden was based on test pricing from two commercial laboratories that might not reflect all commercial laboratories. Hence, the cost analysis should be considered only as an estimation.

## Conclusions and relevance

Although many individuals offer conclusions about the inappropriate selection of laboratory tests, there is rarely an opportunity for experts in a given field to review cases in real time and in clinical context and to provide an answer about test utilization. For that reason, the results of this study showing errors in test selection in nearly 75% of the cases result in an evidenced-based review of individual cases.

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