Population-based Study of Repeat Laboratory Testing

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Background: Test repetition could be a readily modifiable component of laboratory utilization. Laboratory test repetition has not been rigorously studied at a population-based level. Our objective was to determine the prevalence of, and charges associated with, repetition of eight common laboratory tests.

Methods: We performed a cross-sectional study using high-quality, population-based clinical databases that included adults in Eastern Ontario, Canada, between September 1999 and September 2000 for incidence of repeating eight common laboratory tests (hemoglobin, sodium, creatinine, thyrotropin, total cholesterol, HDL-cholesterol, ferritin, and hemoglobin A1C). Tests were classified as potentially redundant if repeated within the test’s baseline testing interval. For creatinine, sodium, and hemoglobin, only tests repeated in the community were considered. For a sensitivity analysis, we varied the repeat interval by 25%, excluded tests repeated by different physicians, and excluded repeats of normal tests.

Results: Almost 4 million tests were conducted during the study year. Most tests (76%) were conducted on patients in the community. More than one-half of all people in the population had at least one laboratory test, with an overall testing rate of 367 tests per 100 people per year. Repeat testing within 1 month accounted for 30% of all utilization (109 repeat tests per 100 people per year). Repetition was more common in hospitalized patients, varied extensively among tests, and was concentrated in a limited number of people. For the eight tests included in the study, charges of potentially redundant repetition in adults totaled between $13.9 and $35.9 million (Canadian) annually.

Conclusions: Laboratory test repetition is very common, makes up a significant component of overall test utilization, and is costly.

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During the last several decades, laboratory utilization has increased throughout the world (1–5). Although the evidence supporting the claim is weak (6), there is a perception that inappropriate laboratory utilization is widely prevalent and explains a significant portion of increased laboratory utilization (7–11). As with other areas of physician behavior (12), improving laboratory utilization has been difficult (13, 14). Repeat testing is one component of laboratory utilization that could be modified (6, 15). Primarily, this is because tests may be repeated when the previous result is unavailable or the ordering physician is unaware that the test was performed previously (5, 16–18). Information technology can decrease repeat testing by presenting previous test results (19) or the probability that a test will be abnormal (20). Because repeat testing is an area of laboratory utilization that could be readily modifiable, it requires further study.

Previous investigations have studied repeat testing in the community (21), in hospitals (17, 22–24), or when patients are transferred from the community into the hospital (25–27). Over an 8-month period in The Netherlands, 38% of common laboratory tests in the community had been conducted previously during that time period (21). Test repetition is also common if patients are admitted to hospital. Rix and Stump (26) found that only 3.1% of tests conducted during the first day of hospitalization had been performed in the week before admission; however, 71% (25) and 63% (27) of tests conducted in the week and year before admission, respectively, were repeated during the hospitalization. Repeat testing is very common during hospitalization. Dixon and Laszlo (23) found that the tests on almost all inpatients were repeated, even when the initial chemical profile was normal. At the Brigham and Women’s Hospital, 28.2% of
78,798 common laboratory tests were repeated unnecessarily early (24). Valenstein et al. (22) found that 27% of 936 inpatient, non-intensive care unit chemistry profiles had been measured previously that day (17). In the intensive care unit, 82.8% of electrolyte profiles of 145 patients had been measured previously that day (22).

To accurately measure repeat laboratory testing, a population-based assessment is optimal. This allows laboratory utilization to be studied for everyone within a geographic area, rather than within a particular hospital or health services organization. A population-based analysis allows laboratory utilization to be followed even when patients transfer between different sectors of the healthcare system, such as from the community to the hospital. Finally, a population-based analysis produces unbiased utilization rates because a true denominator (i.e., all people in a particular area) rather than a “pseudo denominator” (i.e., all people who had a laboratory test) is used. This is necessary to meaningfully compare repeat laboratory testing to the utilization of other health services. This study is a population-based examination of repeat laboratory testing in the community and hospital for people in Eastern Ontario, Canada.

**Materials and Methods**

**STUDY AREA**

Ontario is Canada’s most populous province, with 11.7 million people in 2000. This study included all adults living in Eastern Ontario, defined here as the area east of a line connecting the towns of Arnprior in the north with Trenton in the south. In 2000, this area contained 1.09 million people 18 years or older.

**LABORATORY TESTS**

In Ontario, medical laboratory testing is provided by private and hospital-based laboratories. With some exceptions, the former provide laboratory testing exclusively to community-based patients. Hospital-based laboratories provide testing primarily to hospitalized patients but also to community patients who attend hospital-based clinics or in areas where private laboratories are unavailable.

All private laboratories operating in Eastern Ontario participated in the study (see Appendix A). All hospitals in the area participated as well (Appendix A) except for those in Hawkesbury and Cornwall. This was primarily attributable to technical limitations of the laboratory information systems within these institutions that precluded them from participating in the study. On the basis of the data collected for the study, we estimate that our sample missed 1.5% of all tests in Eastern Ontario. The study was approved by the ethics review board of the Ottawa Hospital as well as the ethics review boards or administrative representatives of all participating institutions.

Because a study of all tests would have been infeasible, we examined the utilization of eight laboratory tests. These included a mixture of common (including hemoglobin, creatinine, and sodium) and less common (thyrotropin, total cholesterol, HDL-cholesterol, ferritin, and hemoglobin A1c) laboratory tests. We believed that including such a mixture would increase how representative our sample was for the entire population.

Between September 1, 1999, and September 1, 2000, participating laboratories downloaded the patient identifier, test date, test result, and ordering physician of all study tests from their laboratory information systems. Patients were identified by their Ontario Health Insurance Plan number. Tests were collated into computer files that were encrypted and transferred electronically to the Institute for Clinical Evaluative Sciences. Here a person with written permission to see unencrypted patient identifiers decrypted the entire data file. The Ontario Health Insurance Plan numbers and physician identifiers were then individually encrypted, and the file was stored on a stand-alone and secure computer network. Using these procedures, researchers could study the data file without ever seeing unencrypted patient or physician identifiers. Because it used the same encryption key for patient and physician identifiers, the data file could also be linked to other administrative databases.

**DATABASE LINKAGE**

The Registered Patient’s Database was used to identify each person’s age and sex. The Registered Patient’s Database records basic demographic information for each Ontarian. To determine whether a test was conducted while the patient was in the hospital, we linked to the Discharge Abstract Database, which records the admission and discharge date of all hospitalizations (including same-day surgeries) in Ontario. Tests conducted between the admission and discharge dates were classified as hospital tests. To determine whether a test was conducted while the patient was in the emergency department, we linked to the Physician Services Database, which records claims for physician services. Services conducted in emergency departments are identified by special claim codes. Tests that were ordered on the same date by the same physician who claimed an emergency assessment were classified as emergency tests.

**ANALYSIS**

Using each laboratory’s reference intervals, we determined whether test results were abnormal. Because each laboratory’s testing methodology and reference intervals for each test were similar, we concluded that it was unnecessary to standardize test results. Tests were excluded if there was a missing or invalid patient identifier, if the test had a missing or invalid result, or if patient sex or age was missing. The latter was needed to determine whether the test had a normal result. Because we concentrated on laboratory utilization in adults, tests on patients <18 years of age were also excluded.

To estimate the population of the study, we used 1996 Canadian Census data categorized by the Forward Sortation Area (FSA). The borders of three rural area FSAs...
(K0K, K0H, and K0A) were almost identical to the border for our study area. We summed the population of people 18 years and older of these FSAs and all other Ontario FSAs to the East. We adjusted the 1996 population estimate to 2000 values by use of multipliers that were derived from changes in county-level, age-cohort-specific population changes between 1996 and 2000. The Kaplan–Maier method was used to measure test repetition rates (28). SAS, Ver. 8.2, was used for all analyses.

ESTIMATING PROVINCE-WIDE CHARGES FOR POTENTIALLY REDUNDANT LABORATORY TESTS
We estimated the province-wide charges for potentially redundant laboratory testing. We first used census estimates of the adult population of the study area (1.09 million) and that of the entire province (9.16 million) to estimate the total number of study tests for the entire province. We used a third-party payer perspective to calculate charges for potentially redundant laboratory testing. In Ontario, payment for laboratory tests is determined by the Ministry of Health (29). For this study, charges for hospital tests were identical to those for private laboratories, although such tests are paid out of the hospital’s global budget and not by the Ministry.

Repeat tests are often necessary for proper patient care (30). Determining whether particular tests are appropriate can be difficult, even when primary data are available (6). To estimate the proportion of tests that are potentially redundant, we used the repeat intervals for each presented in Appendix B to determine the time within which test repetition was potentially redundant. Whenever tests could be used for different indications, we always chose the shorter repeat interval to define potentially redundant. As a sensitivity analysis, we varied these repeat intervals.

### Table 1. Annual test frequency, normality, and location.

<table>
<thead>
<tr>
<th>No. of tests (%) of total</th>
<th>Normal tests (%) of test total</th>
<th>Patient location when test was ordered, n (% of test total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>3 978 761 (100)</td>
<td>2 925 582 (73.5) 2 318 438 (58.3) 1 538 239 (38.7)</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>1 177 667 (29.6)</td>
<td>780 635 (66.3) 592 913 (50.3) 44 461 (3.8) 540 293 (45.9)</td>
</tr>
<tr>
<td>Creatinine</td>
<td>859 740 (21.6)</td>
<td>707 608 (82.3) 418 435 (48.7) 37 127 (4.3) 404 178 (47)</td>
</tr>
<tr>
<td>Sodium</td>
<td>671 438 (16.9)</td>
<td>553 125 (82.4) 233 182 (34.7) 38 229 (5.7) 400 027 (59.6)</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>378 743 (9.5)</td>
<td>173 966 (45.9) 322 223 (85.1) 416 (0.1) 56 104 (14.8)</td>
</tr>
<tr>
<td>Thyrotropin</td>
<td>361 218 (9.1)</td>
<td>309 353 (85.6) 305 459 (84.6) 1351 (0.4) 54 408 (15.1)</td>
</tr>
<tr>
<td>HDL-cholesterol</td>
<td>316 309 (7.9)</td>
<td>292 200 (92.4) 269 126 (85.1) 217 (0.1) 46 966 (14.8)</td>
</tr>
<tr>
<td>Hemoglobin A1C</td>
<td>120 260 (3)</td>
<td>38 405 (31.9) 101 817 (84.7) 109 (0.1) 18 334 (15.2)</td>
</tr>
<tr>
<td>Ferritin</td>
<td>93 386 (2.3)</td>
<td>70 290 (75.3) 75 283 (80.6) 174 (0.2) 17 929 (19.2)</td>
</tr>
</tbody>
</table>

*The annual total number of tests is presented. Tests were categorized as normal if they were within reference intervals as specified by the laboratory. Patient location was classified as “hospital” if the Ontario Discharge Abstract Database recorded the patient as hospitalized when the test was ordered. Patient location was classified as “emergency” if the Ontario Physicians Services Database recorded an emergency physician assessment on the day that the test was ordered. The location of all other tests was classified as “community”.

### Table 2. Annual population-based utilization rates and proportion of population having one or more tests.

<table>
<thead>
<tr>
<th>Age groups in years</th>
<th>18 to &lt;36</th>
<th>36 to &lt;50</th>
<th>50 to &lt;65</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>All ages</td>
<td>366/52</td>
<td>169/39</td>
<td>239/43</td>
<td>452/61</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>108/45</td>
<td>65/36</td>
<td>71/37</td>
<td>119/51</td>
</tr>
<tr>
<td>Creatinine</td>
<td>79/34</td>
<td>30/19</td>
<td>45/26</td>
<td>95/44</td>
</tr>
<tr>
<td>Sodium</td>
<td>62/23</td>
<td>20/11</td>
<td>30/15</td>
<td>69/27</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>35/26</td>
<td>14/12</td>
<td>29/23</td>
<td>57/41</td>
</tr>
<tr>
<td>Thyrotropin</td>
<td>33/25</td>
<td>22/18</td>
<td>28/22</td>
<td>38/30</td>
</tr>
<tr>
<td>HDL-cholesterol</td>
<td>29/22</td>
<td>9/8</td>
<td>24/20</td>
<td>50/37</td>
</tr>
<tr>
<td>Hemoglobin A1C</td>
<td>11/6</td>
<td>2/8</td>
<td>5/3</td>
<td>17/10</td>
</tr>
<tr>
<td>Ferritin</td>
<td>9/6</td>
<td>7/6</td>
<td>8/6</td>
<td>8/6</td>
</tr>
</tbody>
</table>

*For each age group and for each test, the testing rate (expressed as the number of tests per 100 people per year) and the proportion of the population having at least one test during the year are shown.
Fig. 1. Days to test repetition. The x axis presents time in days; the y axis presents the proportion of tests repeated. (A), results by test; (B), results for all tests by location and normality of the first test.
intervals by a relative increase and decrease of 25%. We used Kaplan–Maier survival curves (28) to determine the proportion of tests repeated within each repeat interval, which was multiplied with the provincial total number of tests to calculate charges. The Kaplan–Maier curves were created for each test in four conditions: (a) including all tests repeated within the repeat interval; (b) excluding tests repeated by the same physician (because physicians should consider the results of each test they order and make appropriate decisions, including whether the test should be repeated, based on this information); (c) excluding repeats where the index was abnormal [because it is often good medical practice to repeat abnormal tests (31)]; and (d) excluding tests that meet either of these criteria. Finally, patients who are seen in the emergency department or in hospital are frequently acutely ill; in these cases, assessment and monitoring of important laboratory values such as sodium, creatinine, and hemoglobin is appropriate. We therefore did not consider such tests as potentially redundant if ordered while the patient was in the emergency department or the hospital.

**Results**

Between September 1, 1999, and September 1, 2000, the participating laboratories conducted a total of 4,277,558 study tests. A total of 298,797 tests (7.0%) were excluded because the patient was <18 years of age (n = 210,076), the test was a duplicate (n = 77,486), the patient had an invalid identifier (n = 4,472), the result was missing (n = 3,717), the patient’s age or gender was missing (n = 2,384), or the test was ordered in the emergency department or the hospital.

**Fig. 2.** Population-based annual charges of potentially redundant repeat testing. The x axis represents testing intervals within which repeat testing was considered potentially redundant. Baseline repeat intervals and the unit charges for each test are presented in Appendix B. Repeat intervals were increased and decreased by a relative 25% (x axis). The y axis represents annual charges (in Canadian dollars) of potentially redundant tests for the entire province. The lines represent charges with different exclusion criteria: when the index test was abnormal (dashed line); repeat tests were ordered by the same physician (black line); the index test was abnormal or the test was ordered by the same physician (dotted line); or all tests were considered (gray line). Creatinine, hemoglobin, and sodium tests repeated when the patient was in the emergency department or the hospital were not considered.

### Table 3. Test repetition rates and proportion of population having a repeated test within four repeat intervals.

<table>
<thead>
<tr>
<th>Test</th>
<th>Overall test rate</th>
<th>Repeat testing rate</th>
<th>% of population having a repeated test</th>
<th>Repeat testing rate</th>
<th>% of population having a repeated test</th>
<th>Repeat testing rate</th>
<th>% of population having a repeated test</th>
<th>Repeat testing rate</th>
<th>% of population having a repeated test</th>
</tr>
</thead>
<tbody>
<tr>
<td>All tests</td>
<td>366</td>
<td>80 (21.7%)</td>
<td>6.5</td>
<td>109</td>
<td>10 (29.8%)</td>
<td>10.1</td>
<td>148 (40.4%)</td>
<td>15.6</td>
<td>229 (62.7%)</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>108</td>
<td>30 (27.9%)</td>
<td>5.7</td>
<td>43</td>
<td>8 (39.7%)</td>
<td>8.3</td>
<td>56 (51.8%)</td>
<td>11.7</td>
<td>78 (72.4%)</td>
</tr>
<tr>
<td>Creatinine</td>
<td>79</td>
<td>23 (29.4%)</td>
<td>4</td>
<td>31</td>
<td>5 (38.9%)</td>
<td>5.6</td>
<td>39 (49.6%)</td>
<td>7.8</td>
<td>55 (69.6%)</td>
</tr>
<tr>
<td>Sodium</td>
<td>62</td>
<td>24 (38.7%)</td>
<td>3.7</td>
<td>30</td>
<td>4 (48.6%)</td>
<td>4.9</td>
<td>36 (58.2%)</td>
<td>6.3</td>
<td>46 (74.1%)</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>35</td>
<td>6.0 (1.7%)</td>
<td>0.3</td>
<td>1</td>
<td>0 (3.8%)</td>
<td>0.8</td>
<td>4 (12.7%)</td>
<td>2.5</td>
<td>14 (40.6%)</td>
</tr>
<tr>
<td>Thryotropin</td>
<td>33</td>
<td>0.8 (2.5%)</td>
<td>0.4</td>
<td>2</td>
<td>0 (5.4%)</td>
<td>1</td>
<td>5 (14.4%)</td>
<td>2.5</td>
<td>13 (40.7%)</td>
</tr>
<tr>
<td>HDL</td>
<td>29</td>
<td>0.4 (1.5%)</td>
<td>0.2</td>
<td>1</td>
<td>0 (2.9%)</td>
<td>0.5</td>
<td>3 (11.1%)</td>
<td>1.9</td>
<td>12 (39.7%)</td>
</tr>
<tr>
<td>Hemoglobin A1C</td>
<td>11</td>
<td>0.2 (2.0%)</td>
<td>0.1</td>
<td>1</td>
<td>0 (6.4%)</td>
<td>0.4</td>
<td>3 (26.0%)</td>
<td>1.3</td>
<td>8 (68.3%)</td>
</tr>
<tr>
<td>Ferritin</td>
<td>9</td>
<td>0.2 (2.4%)</td>
<td>0.1</td>
<td>0.6</td>
<td>0 (7.0%)</td>
<td>0.3</td>
<td>1.7 (18.8%)</td>
<td>0.7</td>
<td>3.7 (40.6%)</td>
</tr>
</tbody>
</table>

*a* All rates are expressed as number of tests per 100 people per year.

*b* Values in parentheses are the percentages of the overall test rate.
or the test was initiated by the laboratory as a check (n = 662). This left a total of 3,978,761 tests in our study (Table 1). Hemoglobin, creatinine, and sodium were the most common, accounting for 68.1% of all tests. These tests were also more likely to be conducted in the emergency department or in the hospital. Cholesterol and hemoglobin A1C were least likely to have normal results (45.9% and 31.9%, respectively).

Population-based test utilization rates and the proportion of the population having at least one test during the study year are presented in Table 2. The eight study tests were commonly used with an overall rate of 366 tests per 100 people per year. Test rates ranged from 9 per 100 people-years for ferritin to 108 tests per 100 people-years for hemoglobin. Test rates varied extensively among age groups, with test utilization being highest in the eldest quartile for all tests except total and HDL-cholesterol. Slightly more than one-half of the population had at least one test during the study year. This proportion varied extensively among tests (6% for ferritin to 45% for hemoglobin). The proportion of adults having one or more tests increased with age, with almost three-fourths of adults over 65 years of age having at least one of the study tests.

**REPEAT TESTING**

The probabilities that tests were repeated during the study year are shown in Fig. 1A. Overall, tests were repeated very rapidly at the start of observation, with 22% of tests being repeated within 1 week. By the end of the year, 63% of all tests had been repeated. Test repetition varied extensively among the tests. Common tests, such as hemoglobin and sodium, were repeated very quickly at the start of observation. Other tests, most notably that for hemoglobin A1C, had a repetition curve that was sinusoidal in shape. At the end of the test year, the probability that tests were repeated ranged from 40% for ferritin, thyrotropin, and total and HDL-cholesterol to 74% for sodium.

Two factors affecting test repetition are illustrated in Fig. 1B. The location and the result of the index test strongly influenced time to test repetition. Index tests conducted while the patient was in the hospital or the emergency room were repeated much more quickly than when patients were in the community. In each location, tests were repeated more quickly when the index test was abnormal.

The population-based measures of repeat testing are presented in Table 3. When all tests were considered together, we found a 1-week test repetition rate of 80 tests per 100 people per year. This accounted for 21.7% of all test utilization. During the year, 23% of the population had a repeat test. As the repeat interval increased, the test repetition rate also increased, with a 1-year repetition rate of 229 tests per 100 people per year. Repetition rates varied extensively among tests. For example, at 1 week, tests with the overall highest utilization rates, including hemoglobin, creatinine, and sodium, had repeat testing rates that were considerably greater than the rates for the other tests (Table 3).

**POTENTIALLY REDUNDANT REPETITION**

The total annual charges for potentially redundant utilization of the eight study tests for adults in the province are presented in Fig. 2. Extrapolating our data to the entire province, we estimated that there would be a total of 33.5 million study tests annually (365 tests per 100 persons per year) with total charges of $215.2 million (Canadian).

With the baseline testing repeat presented in Appendix B, potentially redundant rates varied between 49.4 and 153.5 tests per 100 persons per year, depending on the exclusion criteria and the repeat testing interval used to label tests as potentially redundant. With no exclusions, redundant testing rates varied from 4.4 tests per 100 for HDL to 33.5 tests per 100 for creatinine.

For the tests included in this study, potentially redundant laboratory repetition consumed between $13.9 million and $35.9 million annually, depending on the exclusion criteria and the repeat interval that was used (Fig. 2). This comprises 6.5–16.7% of total charges for the study tests annually.

**Discussion**

To our knowledge, this is the first study of laboratory utilization that includes all sectors of a healthcare system, including tests performed in hospitals, emergency departments, and the community. We found that the tests included in our study were conducted on almost one-half of the population with a high utilization rate. These tests were commonly repeated, and a large proportion of test utilization was consumed by test repetition. Potentially redundant tests were common and expensive.

Laboratory utilization consumes considerable resources, even when direct costs alone are considered (1–5). Repeat tests are a special component of laboratory utilization because they could be particularly conducive to modification, especially by improving the dissemination of results among physicians (5, 6, 15–18). Our study shows that tests are frequently repeated. Of the tests included in our study, repeats within 3 months accounted for 40.4% of overall test utilization. Even with conservative criteria, we found that potentially redundant tests are common. Despite the small unit cost of these tests, the frequent use of them brought the total annual charges of potentially redundant repetition up to $35.9 million. It should be noted that charges for medical technologies are generally much higher than costs in the United States, especially with regard to laboratory tests. The frequency and cost of repeat testing indicate that overall test utilization could be heavily influenced by targeting repeat testing alone.

To design and improve interventions that influence test repetition, we should identify the patient and system factors that are associated with repeat testing. In this
report, we identified the location and normality of the index test as two factors that strongly influenced time to repetition. Other patient, physician, and test factors could influence repeat testing, such as patient age, severity of illness, whether the repeating physician ordered the initial test, location of patient assessment, and test type. Further research in this area could help explain why tests are repeated and help us to expand on interventions that have been shown to reduce the frequency or charges associated with repeat tests, as illustrated in two published studies (19, 32).

There are interesting comparisons between our study and previous investigations of laboratory repetition. One previous study of laboratory repetition in the community found a repetition rate of 38% over an 8-month period (21). We noted a considerably higher repetition rate of 56% as determined from the Kaplan–Maier curve in Fig. 1A. This higher estimate is likely attributable to the inclusion of all healthcare sectors rather than just community patients. In addition, use of Kaplan–Maier methodology avoided underestimating repetition when index tests were conducted late in the study period. Our study confirms that test repetition is especially common for hospitalized patients (17, 23, 24), although some of this repetition is appropriate because of the acuity of hospitalized patients.

Potentially redundant laboratory tests are an especially important component of repeat testing because they might be especially conducive to interventions that decrease utilization. Although our study shows that potentially redundant tests are relatively common, there are several reasons that our study could underestimate the potential savings from abolishing such tests. The first reason is that our study only included eight common tests. If other laboratory tests have similar redundant rates, the potential savings from decreasing the utilization of all tests would be considerable. The second reason is that our criteria for “potentially redundant” were inexact. It is possible that tests that do not meet our criteria were also redundant. Although it is also very possible that tests deemed by our criteria as potentially redundant were completely valid, we believe that our estimates for redundant test repetition rates and charges are likely conservative given the conservative repeat intervals that we chose for the study (Appendix B). Despite these uncertainties, we believe that our study is still important for achieving an approximate measure of redundant testing. The third reason is that our study missed laboratory tests from three hospitals in the study area. Although tests in these centers likely comprised only 1.5% of all such tests, test repetition rates in our study will be underestimated without them.

Our study has other limitations. One is that, given the scope of the study and its reliance on administrative data, we had no clinical information surrounding each test. Such information could have made classification of test redundancy, which was admittedly crude in this study, more reliable. Such data, perhaps along with prospectively collected information, would also allow us to determine whether index tests were clinically indicated, further enhancing our classification of redundant testing. Another limitation is that we measured test charges and not costs, which can be divergent (33). Costs, along with the expense of resources consumed because of the repeat tests, would be required to accurately assess the consequences of redundant repeat testing. A third reason is that we extrapolated utilization rates from Eastern Ontario to the rest of the province to estimate total charges. Because utilization rates for other healthcare resources can vary among sectors of the province (34, 35), we are uncertain of the accuracy of our extrapolations to the entire province.

Despite these issues, our study shows that repeat laboratory tests make up a considerable proportion of overall test utilization. It also shows that potentially redundant laboratory utilization is common and costly. We believe that these observations show that repeat testing is an area of utilization that could be targeted with interventions to decrease repeat testing and decrease health expenditures.

This project was supported by a program grant from the Ontario Association of Medical Laboratories. Dr. van Walraven is an Ontario Ministry of Health Career Scientist.

References
behavior of physicians ordering laboratory tests: a literature study. Med Care 1993;31:784–94.
Appendix A

Members of the Network of Eastern Ontario Medical Laboratories (NEO-MeL).

Private medical laboratories
- Bio-Test Laboratory Inc.
- Canadian Medical Laboratories Limited
- Gamma-Dynacare Medical Laboratories
- MDS International

Hospitals
- Ottawa Hospital—Civic, General, and Riverside Campus
- Queensway-Carleton Hospital
- Children’s Hospital of Eastern Ontario
- Montfort Hospital, Ottawa
- Arnprior and District Memorial Hospital
- Almonte General Hospital
- Carleton Place and District Memorial Hospital
- Perth and Smiths Falls District Hospital
- Winchester District Memorial Hospital
- Glengarry Memorial Hospital
- Kingston General Hospital
- Hotel Dieu Hospital, Kingston
- Quinte Health Care Belleville General, Belleville
- Quinte Health Care Trenton Memorial, Trenton
- Prince Edward County Memorial Hospital, Picton

Appendix B

Test unit charges and repeat intervals

<table>
<thead>
<tr>
<th>Test</th>
<th>Unit charge</th>
<th>Repeat interval</th>
<th>Justification of repeat interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin</td>
<td>$8.27</td>
<td>10 days</td>
<td>Arbitrary, but tests repeated when the patient was in the emergency department or the hospital were excluded</td>
</tr>
<tr>
<td>Creatinine</td>
<td>$2.58</td>
<td>10 days</td>
<td>See hemoglobin</td>
</tr>
<tr>
<td>Sodium</td>
<td>$2.58</td>
<td>10 days</td>
<td>See hemoglobin</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>$2.58</td>
<td>6 weeks</td>
<td>Time recommended before lipoprotein measurements are repeated after start of, or change in dose of, antilipemia medications (36, 37)</td>
</tr>
<tr>
<td>Thyrotropin</td>
<td>$14.48</td>
<td>6 weeks</td>
<td>Time recommended before repeating thyrotropin measurements after adjustment of thyroxine dose (38, 39)</td>
</tr>
<tr>
<td>HDL</td>
<td>$9.31</td>
<td>6 weeks</td>
<td>See total cholesterol</td>
</tr>
<tr>
<td>Hemoglobin A1C</td>
<td>$11.37</td>
<td>12 weeks</td>
<td>Measures glycemic control of previous 2–3 months (40, 41)</td>
</tr>
<tr>
<td>Ferritin</td>
<td>$14.48</td>
<td>8 weeks</td>
<td>After an acute blood loss, a median of 8 weeks is required to reach the baseline hemoglobin (assuming a normal bone marrow and no substrate deficiencies) (42). If the index ferritin was measured on the same day as the acute blood loss, this would be the minimum time within which ferritin should be rechecked to ensure adequate iron stores because erythropoiesis is the major sink for iron stores</td>
</tr>
</tbody>
</table>

*All charges are given in 2000 Canadian dollars and are the amounts paid to laboratories by the Ontario Ministry of Health (29). Tests conducted by hospital laboratories are paid out of the hospital’s global budget. Therefore, these figures represent charges if all tests were charged to the Ministry.