Assessment of Decision Support for Blood Test Ordering in Primary Care

A Randomized Trial

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Background: **Different methods for changing blood test–ordering behavior in primary care have been proven effective. However, randomized trials comparing these methods are lacking.**

Objective: **To compare the effect of two versions of BloodLink, a computer-based clinical decision support system, on blood test ordering among general practitioners.**

Design: **Randomized trial.**

Setting: **44 practices of general practitioners in the region of Delft, the Netherlands.**

Participants: **60 general practitioners in 44 practices who used computer-based patient records in their practices.**

Intervention: **After stratification by solo practices and group practices, practices were randomly assigned to use BloodLink-Restricted, which initially displays a reduced list of tests, or BloodLink-Guideline, which is based on the guidelines of the Dutch College of General Practitioners.**

Measurements: **Average number of blood tests ordered per order form per practice.**

Results: **General practitioners who used BloodLink-Guideline requested 20% fewer tests on average than did practitioners who used BloodLink-Restricted (mean [±SD], 5.5 ± 0.9 tests vs. 6.9 ± 1.6 tests, respectively; $P = 0.003$, Mann–Whitney test).**

Conclusions: **Decision support based on guidelines is more effective in changing blood test–ordering behavior than is decision support based on initially displaying a limited number of tests. Guideline-driven decision support systems can be effective in reducing the number of laboratory tests ordered by primary care practitioners.**

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The majority of general practitioners in the Netherlands have replaced traditional paper-based patient records with computer-based records; physicians enter patient data themselves in the computer during patient encounters (1). The use of electronic patient records creates new opportunities to influence physician behavior through implementation of decision support systems (2–7). In recent years, researchers have documented various computer-based decision support systems that have influenced physician behavior (8–17). Other investigators, however, have reported that computer-based decision support has not affected patient care (18). To resolve the issue, investigators have compared the results of studies that were conducted in different settings, used different methods, and involved different populations (19). Studies comparing different methods of providing computer-based decision support in randomized trials are not available.

In the Netherlands, 3% to 4% of patient encounters with general practitioners in primary care result in the ordering of blood tests (20). However, ordering of blood tests is not always appropriate (21–29). Researchers argue that excessive ordering of tests causes physicians to pursue evaluation of false-positive results, which in turn leads to additional unnecessary diagnostic examinations (30–35). Two methods have proven effective in reducing the number of tests ordered by Dutch general practitioners. The first method is based on restricting the number of tests that are listed on an order form. Zaat and colleagues (36, 37) developed a restricted paper order form that replaced the existing form. The second method involves introduction of indication-oriented order forms that are based on clinical practice guidelines (38–40).

We hypothesized that an indication-oriented order form based on guidelines, which would provide an optimally "restricted" list of tests that are relevant for a specific indication, would be more effective in decreasing the number of tests ordered compared with an order form that provides an initially limited list of tests. We therefore conducted a randomized trial to compare the effect of two versions of BloodLink, a computer-based

clinical decision support system, on blood test ordering among Dutch general practitioners.

METHODS

Participants

In August and September 1995, all 64 practices (94 general practitioners) in the region of Delft, the Netherlands, were invited to participate in the study. Only practices that had replaced their paper-based patient records with electronic records and were using the computer during patient encounters were eligible. A total of 46 practices (62 general practitioners) agreed to participate.

Randomization

To avoid contamination, we performed random allocation at the level of the practice (41, 42). The practices were first stratified by type: solo practices or group practices (two or more general practitioners in the same practice). Each practice was subsequently assigned by simple random allocation to use BloodLink-Restricted or BloodLink-Guideline for the full study period. A researcher who was not involved in the study and was blinded to the identity of the practices performed the randomization by using a random-numbers table. After randomization, 22 practices involving 30 general practitioners were assigned to use BloodLink-Restricted and 24 practices involving 32 general practitioners were assigned to use BloodLink-Guideline.

Intervention

We developed two versions of BloodLink, a computer-based decision support system. BloodLink-Restricted initially displays a reduced list of tests, whereas BloodLink-Guideline is based on the guidelines of the Dutch College of General Practitioners. Both versions of BloodLink are integrated with the computer-based patient record (43).

The option to use BloodLink was added to the screen that the general practitioner uses when entering data in the electronic patient record during patient encounters. The general practitioner can activate BloodLink to order blood tests as an alternative to using paper order forms. Because the total number of tests that can be ordered is too large to display on a computer screen, a set of tests is presented for selection. If the physician requires additional tests that are not currently displayed, he or she can type the first few letters of the names of the required tests, and the system will present all possible matches (including those corresponding to possible typing errors of the general practitioner) for selection. The number of tests that the general practitioners had at their disposal was the same both before and during the intervention (52 clinical chemistry tests and 46 microbiological tests). Options for specific instructions to the laboratory (for example, "urgent processing" or "fasting values") are available. Once the physician has made his or her selections, BloodLink prints a patient-specific test order form and instructions for the laboratory and updates the patient record with the tests that have been ordered. The only difference between the two versions of BloodLink is the method used to present the initial set of tests to the general practitioner.

BloodLink-Restricted is based on the idea of a restricted order form. It offers the general practitioner an initial set of 15 tests that have been shown to cover most of the clinical situations seen in primary care (36). BloodLink-Restricted can be viewed as a general electronic order form that presents only 15 tests on the screen, together with a field labeled "other tests" that allows the physician to request any other blood test (43). The 15 tests are alanine aminotransferase, aspartate aminotransferase, total bilirubin, cholesterol, creatinine, erythrocyte sedimentation rate, free thyroxine, γ-glutamyltransferase, glucose (and fasting glucose), glycosylated hemoglobin, hemoglobin, mean corpuscular volume, Paul–Bunnell, potassium, and thyroid-stimulating hormone. At any time, the physician can customize tests for individual patients by adding or deleting tests.

BloodLink-Guideline is based on the guidelines of the Dutch College of General Practitioners. By January 1996, the Dutch College of General Practitioners had published 54 guidelines. Some guidelines focus on symptoms that are frequently seen in the primary care setting, such as acute diarrhea, acute sore throat, low back pain, alcohol abuse, fever in children, and sleeping disorders. Other guidelines focus on common diseases in primary care, such as diabetes, asthma, depression, dementia, and eczema. Finally, a set of guidelines covers preventive medicine. We reviewed the most recent version of each guideline, available in January 1996, and noted whether it contained a reference to a blood test (44). We determined the clinical situation in which the

test should be performed (indication) and the tests that should be performed in that situation (advised tests).

When general practitioners activate the system, BloodLink-Guideline first provides an overview of the available guidelines. The names of these guidelines are familiar to Dutch general practitioners. The general practitioner selects the appropriate guideline. A guideline may describe several different indications for requesting blood tests; for example, the guideline for blood tests and liver disease mentions 10 different indications. After the indication has been identified, the system proposes the relevant tests. The general practitioner then decides whether to adhere to the protocol. At any time, the physician can customize tests for individual patients by adding or removing tests from the proposed list. Although new guidelines are published at regular intervals, the currently available guidelines cover only a limited set of indications for blood tests (44). In the absence of national guidelines, local or regional guidelines may be used.

The version of BloodLink-Guideline used during the clinical trial in the Delft region included three regional guidelines for anemia, AIDS, and clotting disorders, in addition to all national guidelines. Even with these additional guidelines, BloodLink-Guideline does not cover all possible indications for blood tests in primary care. To deal with these situations, the general practitioner can select the heading "other indication" and order any test.

Protocol

Before the study, the general practitioners were using two paper order forms: one for clinical chemistry and one for microbiology. After BloodLink was installed, one of the authors gave a brief orientation presentation to the participating practitioners. During a 3-month phase-in period, the general practitioners were allowed to use BloodLink in their practices to become acquainted with the system. After this period, the general practitioners were asked whether they were willing to participate in the trial. The study period was March 1996 through February 1997.

Physicians always had the choice to use either the BloodLink software or the paper forms to order clinical chemistry and microbiology tests; thus, paper order forms were still available during the entire intervention period. When the general practitioner ordered blood tests during a patient encounter, only one order form was generated regardless of whether the general practitioner used paper forms or BloodLink. The electronic patient record monitored use of BloodLink by the practitioners. To include the requests for blood tests that were made by using traditional paper forms, we retrieved from the regional laboratory all requests for blood tests.

Outcomes

We counted the number of order forms that the laboratory received from the general practitioners and the number of tests on each form. The main outcome measure was the average number of tests per order form (including paper forms) per practice (summary variable). We defined the most frequently ordered tests as the tests that accounted for 80% of the total number of tests ordered. For these tests, we computed per practice the percentage of order forms that included the test.

Statistical Analysis

We used *t*-tests to compare the distribution of baseline characteristics of practices and general practitioners. The differences in the number of tests per order form were analyzed by using the Mann–Whitney test, with practice as the unit of analysis. We conducted a multivariate Poisson regression analysis to estimate the difference in number of tests per order form between the two intervention groups while controlling for historic (1 July 1994 through 30 June 1995) test-ordering behavior of the general practitioners, size of the practice, and composition of the practice (sex of the patients, average patient age, and type of insurance). For all analyses, we used the number of tests as a count variable and the number of forms as an offset variable. Since the number of tests does not follow a Poisson distribution, we adjusted the standard errors for overdispersion (scale parameter estimated by using the square root of the Pearson chi-square value divided by the degrees of freedom). For frequently ordered tests, we computed per practice the percentage of order forms that included that test and then applied the Student *t*-test; equal variance was not assumed, and the unit of analysis was the practice. All analyses were performed by using SAS statistical soft-

Table 1. **Baseline Characteristics of Practices**

Characteristic	BloodLink-Restricted Group ($n = 21$)		BloodLink-Guideline Group ($n = 23$)		*P* Value*
	Mean	Median (25th, 75th percentiles)	Mean	Median (25th, 75th percentiles)	
Enrolled patients, *n*	3683	3399 (2930, 4400)	3411	3205 (2917, 3796)	>0.2
Patient age, *y*	36.3	36.3 (35.1, 37.8)	37.1	37.6 (35.0, 39.4)	>0.2
Female patients, %	48.3	49.4 (48.2, 50.0)	49.5	49.9 (49.0, 50.3)	>0.2
Patients insured through government insurance, %	53.2	53.5 (50.9, 56.4)	52.9	53.7 (50.7, 58.9)	>0.2
Tests per order form from 1 July 1994 through 30 June 1995, *n*†	7.7	7.8 (5.8, 9.3)	7.2	7.3 (6.1, 8.1)	>0.2

* By *t*-test on means.
† Two practices missing in each group.

ware, version 6.12 (SAS Institute, Inc., Cary, North Carolina).

Role of the Funding Source

Our funding source, the European Commission, had no influence on the collection, analysis, or interpretation of the data or in the decision to submit the study for publication.

RESULTS

BloodLink software was installed in 46 practices. During the 3-month phase-in period, two solo practitioners did not want to proceed with the experiment; one practitioner assigned to BloodLink-Restricted stated that the response time of his computer had deteriorated with use of the software, and one practitioner assigned to BloodLink-Guideline did not like the software. Thus, 44 practices consisting of 60 general practitioners completed the study (21 practices involving 29 general practitioners were assigned to BloodLink-Restricted and 23 practices involving 31 general practitioners were assigned to BloodLink-Guideline).

Baseline Data

As of 1 March 1996, 77 336 patients were enrolled in the practices assigned to BloodLink-Restricted. Of these patients, 41 174 (53.2%) were insured through government insurance, 37 397 (48.4%) were female, and the average age was 36.2 years (median, 33.7 years [25th and 75th percentiles, 21.0 and 50.6 years]). A total of 78 461 patients were enrolled in the practices assigned to BloodLink-Guideline as of 1 March 1996; 41 198 (52.5%) patients were insured through government insurance, 38 743 (49.9%) were female, and the average age was 37.1 years (median, 34.7 years [25th and 75th percentiles, 21.5 and 51.9 years]). **Table 1** shows the baseline characteristics of the practices involved in the study. **Table 2** shows the baseline characteristics of the general practitioners.

Tests per Order Form per Practice

The general practitioner had the choice of using BloodLink or a paper form to order tests. Of the 12 742 order forms that the laboratory received from practices using BloodLink-Restricted, 11 151 orders (88%) were made by using the software; the remaining 1591 orders were placed by using traditional paper order forms. Of the 12 668 orders placed by the practices using BloodLink-Guideline, 9091 (71%) were generated by using the decision support system. We calculated as a summary variable the average number of tests ordered per order form per practice. General practitioners who had access to BloodLink-Guideline ordered 20% fewer tests per form than did general practitioners who had access to BloodLink-Restricted (mean [±SD], 5.5 ± 0.9 tests vs. 6.9 ± 1.6 tests [median, 6.6 vs. 4.6], respectively; $P = 0.003$, Mann–Whitney test).

Table 3 shows the results of multivariate Poisson regression analysis comparing the number of tests per order form with use of BloodLink-Restricted or BloodLink-Guideline, adjusted for practice characteristics and historic test-ordering behavior. These results are similar to those found in univariate comparisons. The group that used BloodLink-Restricted ordered 19% more tests per order form than did the group that used BloodLink Guideline. No demographic practice variable was independently associated with the number of tests per order form. Practices that ordered more tests before the inter-

Table 2. **Baseline Characteristics of General Practitioners***

Characteristic	BloodLink-Restricted Group ($n = 29$)		BloodLink-Guideline Group ($n = 31$)		*P* Value†
	Mean	Median (25th, 75th percentiles)	Mean	Median (25th, 75th percentiles)	
Age at start of study, *y*	43.7	42.0 (38.7, 48.2)	43.2	43.0 (39.0, 47.0)	>0.2
Experience at start of study, *y*	16.5	15.0 (12.5, 22.2)	15.6	16.0 (12.0, 20.0)	>0.2
CME credits in 1996	44.3	42.0 (33.7, 56.5)	43.1	42.0 (31.0, 50.0)	>0.2
CME credits in 1997	51.7	47.0 (38.0, 56.5)	43.7	43.0 (31.0, 60.0)	0.126

* CME = continuing medical education.
† By *t*-test on means.

vention continued to order more tests per form, independent of the type of form.

The general practitioners ordered 157 360 tests in total during the study period. Although the practitioners requested 351 different laboratory tests, the 20 most frequently ordered tests accounted for 80% of the total number of ordered tests (**Table 4**). **Table 4** also shows the percentage of order forms per practice that included that test. In the BloodLink-Restricted group, for example, 61.2% of the order forms included an erythrocyte sedimentation rate test, compared with 44.1% in the BloodLink-Guideline group ($P < 0.001$, Student *t*-test).

DISCUSSION

Physicians who used BloodLink-Guideline, an indication-oriented test-ordering system, ordered fewer tests per form compared with those who used BloodLink-Restricted, which initially presented a limited list of tests (5.5 tests vs. 6.9 tests). For some frequently ordered tests, the difference between the BloodLink-Guideline and BloodLink-Restricted groups was large; we observed differences of 28% for erythrocyte sedimentation rate, 32% for creatinine concentration, 46% for γ-glutamyltransferase level, and 49% for aspartate aminotransferase level (**Table 4**). For other tests, however, there were no significant differences (for example, glucose, cholesterol, thyroid-stimulating hormone, and high-density lipoprotein cholesterol levels; erythrocyte count; and sodium and alkaline phosphatase levels). We conclude that the overall reduction of ordered tests in the BloodLink-Guideline group was caused predominantly by a decrease in the ordering of some specific tests. BloodLink-Guideline does not reduce all test ordering to the same degree, but instead singles out various tests.

Table 3. **Association between the Number of Tests per Form and Type of Form***

Factor	Relative Risk (95% CI)†
Use of BloodLink-Guideline order form	1.0 (referent)
Use of BloodLink-Restricted order form	1.19 (1.10–1.29)
Average number of tests per form in the year before the start of the study (per 1% increase)	1.12 (1.10–1.15)
Percentage of women (per 1% increase)	2.15 (0.23–20.6)
Percentage of patients with government insurance	0.63 (0.23–20.6)

* Two practices are missing from each group because data on historic ordering behavior are lacking.
† Based on multivariate Poisson regression model and adjusted for the factors listed in the table and practice size.

Increasingly, the literature shows that provision of decision support can change health care delivery (8–13, 15). BloodLink-Guideline, which is based on five categories of indications and involves 68 different indications (44), manages the ordering of 37 different tests; in contrast, BloodLink-Restricted initially lists 15 tests in alphabetical order. Use of BloodLink-Guideline resulted in a much larger reduction in ordered tests.

A limitation of our study is the absence of a gold standard to judge whether the reduction in the number of ordered tests translates into more appropriate ordering patterns. Our results, however, indicate that with regard to blood test ordering, providing more options that are embedded in a system driven by guidelines leads to a larger reduction in the number of tests ordered than does merely reducing the form to a limited set of tests. This larger reduction can be explained by the fact that BloodLink-Guideline shows an "optimal" restricted list of tests relevant for a specific indication. BloodLink-Guideline can be regarded as an attempt to limit the number of choices available on the basis of medical knowledge about a specific indication. BloodLink-Guideline enables physicians to apply the medical

Table 4. **Order Forms per Practice That Included the 20 Most Frequently Ordered Tests***

Test	Order Forms		*P* Value†
	BloodLink-Restricted Group	BloodLink-Guideline Group	
	%		
Erythrocyte sedimentation rate	61.2 ± 12.0	44.1 ± 10.9	<0.001
Hemoglobin	58.5 ± 11.9	47.8 ± 11.7	0.004
Glucose	47.1 ± 17.4	41.4 ± 12.3	>0.2
Leukocyte count	38.6 ± 15.3	29.7 ± 8.9	0.03
Hematocrit	36.0 ± 21.1	26.6 ± 2.3	0.08
Creatinine	40.0 ± 11.2	27.4 ± 10.8	<0.001
Erythrocyte count	34.7 ± 21.5	24.3 ± 11.6	0.06
Mean corpuscular volume	34.4 ± 21.5	23.0 ± 12.0	0.04
Leukocyte count (differential analysis)	31.3 ± 16.2	23.3 ± 7.2	0.05
Cholesterol	28.7 ± 12.1	25.7 ± 9.0	>0.2
Thyroid-stimulating hormone	26.9 ± 14.3	25.3 ± 5.3	>0.2
γ-Glutamyltransferase	31.3 ± 15.4	16.9 ± 9.2	<0.001
Alanine aminotransferase	24.7 ± 13.6	15.2 ± 6.8	0.008
Potassium	17.7 ± 11.3	8.8 ± 5.4	0.003
Aspartate aminotransferase	16.7 ± 10.8	8.5 ± 6.5	0.005
Triglycerides	11.4 ± 9.9	9.9 ± 6.5	>0.2
High-density lipoprotein cholesterol	11.7 ± 11.1	9.5 ± 6.8	>0.2
Sodium	6.9 ± 7.4	6.2 ± 3.5	>0.2
Free thyroxine	8.4 ± 6.2	4.8 ± 3.7	0.03
Alkaline phosphatase	5.4 ± 4.9	7.0 ± 5.4	>0.2

* Data are presented as the mean ± SD.
† By *t*-test.

knowledge of guidelines, whereas BloodLink-Restricted applies the notion of an initially limited set of tests that should fit most circumstances.

Many investigators have lamented the fact that the availability of guidelines is no guarantee that physicians actually will use them (45–47). Although physicians did not receive formal training in use of the BloodLink software (only brief instruction was given) and the usual paper forms were still available during the intervention period, physicians used BloodLink to place the majority of their orders. Our study provides additional evidence that computer-based decision support systems can be an effective method for incorporating guidelines into daily practice.

Paper forms have been used to change physician behavior in blood test ordering (28, 36, 38–40, 48). Paper forms, however, do not allow expression of the detailed information available in current guidelines. Studies conducted with paper forms, therefore, have been limited to only a few guidelines. Paper forms based on a limited set of guidelines do not solve the fundamental problem of introducing guidelines into clinical practice. BloodLink-Guideline is based on the complete set of recommendations for test ordering provided by the Dutch College of General Practitioners. Although BloodLink could have been used as a stand-alone application, the introduction of BloodLink into daily practice was facilitated by the fact that the general practitioners were already using computer-based patient records.

In conclusion, our study highlights the potential advantage of computer-based patient records as a vehicle for changing physician behavior (49). The results should encourage the adoption of computer-based patient records to enhance test ordering during patient encounters.

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I killed them because I felt a little fatigued and suffered from a slight, persistent cough. Thinking I was overworked and hadn't been getting enough sleep, I went home for a short visit, just a few days to relax in the country while the sweet corn and the raspberries were ripe. From the city I brought fancy ribbon, two boxes of Ambrosia chocolate, and a deadly gift . . . I gave the influenza to my mother, who gave it to my father, or maybe it was the other way around.

Christina Schwarz
Drowning Ruth
New York: Doubleday; 2000

Submitted by:
Fred Campbell, MD
San Antonio, TX 78260

Submissions from readers are welcomed. If the quotation is published, the sender's name will be acknowledged. Please include a complete citation (along with page number on which the quotation was found), as done for any reference.–*The Editor*