Computer-based Blood Test Ordering

Assessment of the effect on physicians' test-ordering behavior

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BloodLink

Computer-based Decision Support for Blood Test Ordering

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BloedLink

Computerondersteunde Besluitvorming bij het Aanvragen van Bloedonderzoek

Evaluatie van het Effect op het Aanvraaggedrag van Huisartsen

Proefschrift

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aan de Erasmus Universiteit Rotterdam
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Voor Anneke, Bart, Annemieke, Marlies, Eric en Frank
Voor Pa en Ma

Contents

Chapter 1

General Introduction

1.1 Test-Ordering Behavior

Requesting blood tests is an important aspect of the health care delivered by the general practitioner in The Netherlands. About three to four percent of the patients' encounters with Dutch general practitioners result in the physician requesting blood tests, which is lower than in many other European countries (1, 2). Although test ordering is limited to three to four percent of patients' encounters with the general practitioner, the use of diagnostic tests in general practice, has known an overwhelming growth in the years behind. Physicians' use of blood tests, however, is not always appropriate (3-8). General practitioners are taught test ordering when training in hospitals before settling down in general practice (9). Hospital morbidity, however, is different from morbidity patterns in general practice (10-12). Appropriate test ordering panels in hospital settings, therefore, are not always appropriate for primary care. Nevertheless, general practitioners use these test panels, once taught, automatically in the primary care setting (13). Uncertainty and the desire not to miss a diagnosis stimulate the use of blood tests (4, 5, 9, 14-16). Excessive and inappropriate test ordering is not only expensive but also may even add to the uncertainty by generating unexpected abnormal or false positive values. The use of blood tests may thus even increase uncertainty and stimulate further unnecessary diagnostic investigations (17, 18). It is important, therefore, that once the decision to obtain blood tests has been made, appropriate test ordering is adhered to. Influencing this heuristic test-ordering behavior has proven to be difficult.

1.2 Continuing Medical Education (CME) in the Delft Region

In the years 1989 through 1993 I was the editor of a local journal the "Huisartsenbulletin" that aimed to inform the general practitioners in the region of Delft about the appropriate use of the laboratory facilities of the Reinier de Graaf Hospital. That hospital performed amongst others, the blood tests requested by the general practitioners in the region. The hospital had the objective to optimize the use of the laboratory facilities and instigated a continuing medical education for the referring general practitioners to achieve

that objective. To facilitate education, the hospital organized round-table conferences: monthly meetings in which the general practitioners could discuss the indications for test ordering with experts in the field. The report of each meeting was published in the "Huisartsenbulletin" and circulated free of charge to all general practitioners in the region.

1.3 Impact of CME on Test-Ordering Behavior

To evaluate the impact of the round-table conferences and the "Huisartsenbulletin" on test ordering behavior of the general practitioners in the Delft region, the Department of General Practice of the Medical School of the Erasmus University was asked to perform a study. The study period was January 1st 1990 through June 31st 1991. The impact on test ordering behavior of two of the round-table conferences (on thyroid-dysfunction testing, October 25th 1990, and on renal-dysfunction testing, November 22nd 1990) and the accompanying publications in the "Huisartsenbulletin" was studied (19). In a before-after study, the test-ordering behavior of two groups of general practitioners was studied. One group consisted of general practitioners who had attended one or both of the conferences and had received the "Huisartsenbulletin"; the other group consisted of general practitioners who did not attend the conferences, but did receive the "Huisartsenbulletin". General practitioners in the Rotterdam region, who did not attend the round-table conferences and did not receive the "Huisartsenbulletin", served as control group. The unit of analysis was the total amount of tests ordered by the general practitioner. The effect on test-ordering behavior of the participating general practitioners was disappointing. The round-table conferences had a temporarily effect on test-ordering behavior, the effect on test-ordering behavior of publishing the "Huisartsenbulletin" was negligible. Having established the ineffectiveness of this type of continuing medical education, we discontinued the conferences, stopped publishing the "Huisartsenbulletin", and started considering other ways of changing test-ordering behavior.

1.4 The Role of Electronic Patient Records

Parallel to our efforts in continuing medical education, general practitioners in the Delft region started using computers to maintain their patient records. In 1991, the medical insurance company active in the Delft region (DSW) initiated a program to provide all general practitioners with computer-based patient records. In 1993, 90 percent of all general practitioners in the Delft region had replaced their traditional paper-based patient records with electronic patient records and used the computer to enter patient data during patient encounters. This use of electronic patient records created new opportunities for the implementation of decision support systems. Integration of decision support facilities with electronic patient records provides a natural way to support clinical practice. Literature documents a range of decision support systems that demonstrated an impact on health-care delivery (20-26). We considered "on site" continuing medical education using a decision-support system to be a possible alternative for the round-table conferences and the "Huisartsenbulletin".

1.5 The Use of Guidelines in Daily Practice

At the same time that the general practitioners in the region of Delft were using electronic patient records in daily practice, the Dutch College of General Practitioners started issuing guidelines for the general practitioner. These guidelines, regularly published in "Huisarts en Wetenschap", the journal of the Dutch College of General Practitioners, assist general practitioners in dealing with specific clinical conditions in a primary care setting, including recommendations for test ordering. Given the fact that previous studies had reported a lack of general practitioners' knowledge concerning indications for tests (6, 27), the guidelines could provide needed support. We believed that applying the guidelines in general practice could result in improved test ordering by general practitioners.

Several studies, however, have shown that the mere existence of guidelines does not necessarily lead to the use of these guidelines by physicians (28-30).

Even when authoritative guidelines are available, changing the behavior of physicians has proven to be difficult (28, 31). Taking the effort to study paper-based guidelines during patient consultation does not seem to be a practical way of working. Every-day time pressure is an understandable obstruction (32). Test ordering based on guidelines has to become part of the normal workflow and should not require excessive additional time.

A possible approach to introducing guidelines into daily practice is to develop a decision-support system based on the available guidelines. In this approach, the paper-based guidelines are replaced by electronic guidelines. Past experience, however, has shown that researchers developing decision support systems based on a guideline may encounter significant problems such as inconsistencies in the guideline, inaccurate or incomplete descriptions of terms, ambiguity, or incompleteness (33-38). This change from paper guidelines to a decision support system, therefore, requires an extensive analysis of the content of the guidelines.

1.6 The Design of a Decision Support System for Test Ordering.

Taking advantage of the use of electronic patient records by Dutch general practitioners, we wanted to replace the traditional test ordering paper forms by a decision support system. Decision support systems based on guidelines may focus on supporting a single guideline for a particular disease, e.g., heart failure, asthma, or diabetes. The objective of the system is to help the practitioner in the management of the patient with a particular disease using the corresponding guideline. Such a system typically covers several aspects of care; these systems provide recommendations for diagnostic investigations, selection of treatment, and follow-up. Unlike systems that focus on a single guideline, we focus on the recommendations for test ordering of all guidelines issued by the Dutch College of General Practitioners. Building a system to change test-ordering behavior, however, requires us to select a method we will follow when providing support.

In The Netherlands, three methods have proven to be effective in changing test-ordering behavior of the general practitioner. Pop and Winkens investigated the influence of personal feedback on test-ordering behavior of Dutch general practitioners. Participating general practitioners ordered blood tests using a paper form on which they also recorded the indication for the tests. Twice a year, an internist provided each general practitioner feedback that compared his or her behavior with the test-ordering behavior of the other participating general practitioners. The internist subsequently discusses the indications and provides suggestions for more rational test ordering. In a three-year period, the total amount of blood tests ordered by general practitioners decreased by a third. (39-43). An important disadvantage of this approach, however, is that it is time consuming and expensive.

Zaat pioneered changing test-ordering behavior by reducing the number of tests available on the order form in The Netherlands (27). Zaat modified the order form by simply removing rarely indicated tests. At the bottom of the order form, space was available in which the general practitioner could write down other tests. Zaat showed in an intervention study that the average number of tests ordered per month decreased by 18 percent after the introduction of the new form (13, 14, 27). A restricted order form is a simple and easy method for reducing the number of tests ordered by general practitioners.

The third method of changing test-ordering behavior of Dutch general practitioners involves the introduction of indication-oriented order forms based on guidelines. On these forms, tests are grouped by indication. These forms proved effective in reducing the number of blood tests ordered by general practitioners (44-46). A major limitation of these studies, however, is that they involve only a small subset of the available practice guidelines.

1.7 Comparing Methods for Changing Test-Ordering Behavior

Although literature shows that different methods are able to change physicians' test-ordering behavior, little is known about which method is most effective. According to Winkens, teaching general practitioners about the validity and diagnostic value of tests is the first step to achieve more appropriate test use (47). On the other hand, Zaat demonstrated that merely reducing the number of tests available on the order form decreases the average number of tests ordered per month by 18%. According to Zaat, the contribution of blood tests is not in assessing important somatic diseases, but in creating a feeling of security (14). Zaat argues that the general practitioner could reach the feeling of security with fewer tests than usually requested. Introducing indication-oriented order forms based on a small subset of guidelines also proved effective in changing test-ordering behavior (44). As the researchers relied on paper forms, the studies have been restricted to only a few indications; the nature of a paper form does not allow the expression of the detail and complexity of the currently available guidelines.

Randomized trials comparing different methods to change test-ordering behavior have never been conducted. We hypothesize that an indication-oriented order form based on guidelines, providing an optimal "restricted" list of tests relevant for a specific indication, will be more effective in decreasing the number of tests ordered than a restricted order form.

We developed two versions of the decision support system BloodLink, using the two different methods. The first version, BloodLink-Restricted, is based on the notion of a restricted order form. The second version, BloodLink-Guideline, is based on the guidelines of the Dutch College of General Practitioners. Both systems were integrated with the general practitioner's electronic patient record.

In the Delft region, the continuing medical education on the use of blood tests had been discontinued in 1993 after the disappointing impact of round-table conferences and "huisartsenbulletins" became evident. In 1996 we were ready to evaluate whether BloodLink would be successful where previous attempts

to change test-ordering behavior had failed. To compare the effect of the two methods embodied in the two BloodLink modules on test-ordering behavior, we performed a randomized clinical trial in the Delft region.

1.8 Improving Guideline Adherence

To deal with the rapidly expanding body of medical knowledge, guidelines are increasingly viewed as a mechanism for distributing knowledge to physicians. Guidelines, however, are explicit but crude summaries of both "state of the art" evidence-based medicine and implicit skills; they should be used not to dictate practice but to inform clinical judgment. Moreover, patients have multiple problems and often present with nonspecific complaints. Protocol adherence, therefore, must be interpreted carefully. When viewing protocol adherence as a goal in itself, explaining the deviations from protocols may take the form of a debate on the barriers that prevent the protocol from being used. We believe that guideline implementation occurs in the context of conflicting pressures for clinical autonomy and professional standardization and quality improvement. (48-50).

One of the objectives of BloodLink-Guideline is to improve adherence to the guidelines of the Dutch College of General Practitioners by implementing a test-ordering module that provides the general practitioner with recommendations for test ordering based on these guidelines. Implementing guidelines in daily practice may lead to more appropriate test ordering by general practitioners and thus reduce the number of tests ordered. An observed reduction of the number of tests requested by the physician, however, does not necessarily mean that the physicians adhere to the protocols. Protocol compliance, therefore, has to be measured by comparing the BloodLink-Guideline test recommendations with the actually ordered tests per indication.

1.9 Outline of this Thesis

Test-ordering behavior of physicians lacks efficiency, resulting in excessive laboratory utilization. Literature documents many attempts to change the test-ordering behavior of physicians. Continuing medical education provided by round-table conferences and the publication of paper reports did not prove to be effective in the Delft region. Guidelines are increasingly viewed as a mechanism for distributing knowledge to physicians. The existence of guidelines, issued by the Dutch College of General Practitioners does not necessarily lead to the use of these guidelines by physicians. Decision support systems have shown to have impact on health-care delivery. Although, in The Netherlands, three methods have proven to be effective in changing test-ordering behavior of the general practitioner, little is known about which method is most effective.

In this study we address the following questions.

Do the practice guidelines of the Dutch College of General Practitioners allow the identification of clear and unambiguous recommendations for blood test ordering in primary care?

This question is discussed in *chapter 2* where we determine the consistency among the practice guidelines of the Dutch College of General Practitioners with respect to the use of blood tests. In this chapter we evaluate whether these guidelines provide a consistent base for the development of a decision support system for ordering.

What are the requirements for providing support when designing a decision support system for test ordering?

This question is dealt with in *chapter 3*. We describe the choices and decisions we had to make, building the two versions of BloodLink, a decision support system to change test ordering in general practice.

Will a further reduction to an indication-oriented test panel be more effective in changing test-ordering behavior than the merely reduction of the number of tests listed on an order form?

This question is answered in *chapter 4*. We describe a randomized trial that assesses which method is most effective in changing test-ordering behavior of general practitioners: the restricted order form or the indication-oriented order form.

To what extent adhere the Dutch general practitioners to the recommendations for test ordering as defined in the guidelines of the Dutch College of General Practitioners?

This question is discussed in *chapter 5* where we assess protocol adherence by comparing the recommendations for test ordering with the actually ordered test(s) per indication.

The main conclusions of this thesis are discussed in *chapter 6* in which we make suggestions for future research as well. The thesis ends with a summary in both English and Dutch.

1.10 References

1. Leurquin P, Van Casteren V, De Maeseneer J. Use of blood tests in general practice: A collaborative study in eight European countries. British Journal of General Practice 1995;45:21-25.
2. Kluijt I, Zaat JOM, Van der Velden J, van Eijk JTM, Schellevis FG. Voor een prikje: Huisarts en bloedonderzoek. Huisarts en Wetenschap 1991;34:67-71 *(The general practitioner and bloodtests. In Dutch, English abstract.).*
3. Kassirer JP. Diagnostic reasoning. Annals of Internal Medicine 1989;110:893-900.
4. Kassirer JP. Our stubborn quest for diagnostic certainty. New England Journal of Medicine 1989;320(22):1489-1491.
5. Ornstein SM, Markert GP, Johnson AH, Rust PF, Afrin LB. The effect of physician personality on laboratory test ordering for hypertensive patients. Medical Care 1988;26(6):536-543.
6. Axt-Adam P, Van der Wouden JC, Van der Does E. Influencing behavior of physicians ordering laboratory tests: A literature study. Medical Care 1993;31:784-794.
7. Eisenberg JM, Nicklin D. Use of diagnostic services by physicians in community practice. Medical Care 1981;19(3):297-309.
8. Wong ET, Lincoln TL. Ready! Fire! ...Aim. Journal of the American Medical Association 1983;250(18):2510-2513.
9. Epstein AM, Begg CB, McNeil BJ. The effect of physicians' training and personality on test ordering for ambulatory patients. American Journal of Public Health 1984;74:1271-1273.
10. Rosser WW. Approach to diagnosis by primary care clinicians and specialists: is there a difference? Journal of Family Practice 1996;42:139-144.
11. Sox HC. Decision-making: a comparison of referral practice and primary care. Journal of Family Practice 1996;42:155-160.
12. Kristiansen IS, Hjortdahl P. The general practitioner and laboratory utilization: why does it vary? Family Practice 1992;9:22-27.
13. Zaat JO, Van Eijk JT, Bonte HA. Laboratory test form design influences test ordering by general practitioners in The Netherlands. Medical Care 1992;30:189-198.
14. Zaat JOM. General practitioners' uncertainty, risk preference, and use of laboratory tests. Medical Care 1992;30(9):846-854.

15. Grol R, Whitfield M, De Maeseneer J, Mokkink H. Attitudes to risk taking in medical decision making among British, Dutch and Belgian general practitioners. British Journal of General Practice 1990;40:134-136.
16. Holtgrave DR, Lawler F, Spann SJ. Physicians' risk attitudes, laboratory usage, and referral decisions: the case of an academic family practice center. Medical Decision Making 1991;11:125-130.
17. Boohaker EA, Ward RE, Uman JE, McCarthy BD. Patient notification and follow-up of abnormal test results. A physician survey. Archives of Internal Medicine 1996;12:327-331.
18. DeKay ML, Asch DA. Is the defensive use of diagnostic tests good for patients, or bad? Medical Decision Making 1998;18:19-28.
19. Axt-Adam P, Van der Wouden JC, Van der Does E. Rondetafelbesprekingen en laboratoriumaanvragen. Het effect van nascholingsbijeenkomsten en verslagen daarvan op het aanvragen van laboratoriumdiagnostiek door de huisarts. In Dutch. Rotterdam: Rotterdams Universitair Huisartsen Instituut; 1992 juni. Report No.: 92-01.
20. Margolis A, Bray BE, Gilbert EM, Warner HR. Computerized practice guidelines for heart failure management: the HeartMan system. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:228-32.
21. Hollingworth GR, Bernstein RM, Viner GS, Remington JS, Wood WE. Prompting for cost-effective test ordering: a randomized controlled trial. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:635-9.
22. Zielstorff RD. Online practice guidelines: issues, obstacles, and future prospects. Journal of the American Medical Informatics Association 1998;5:227-36.
23. Johnston ME, Langton KB, Haynes RB, Mathieu A. Effects of computer-based clinical decision support systems on clinicians' performance and patient outcome. Annals of Internal Medicine 1994;11:497-499.
24. Ohno-Machado L, Gennari JH, Murphy SN, Jain NL, Tu SW, Oliver DE, et al. The guideline interchange format: a model for representing guidelines. Journal of the American Medical Informatics Association 1998;5:357-72.
25. Jenders RA, Hripcsak G, Sideli RV, DuMouchel W, Zhang H, Cimino JJ, et al. Medical decision support: experience with implementing the Arden Syntax at the Columbia Presbyterian Medical Center.

Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:169-173.
26. Smith BJ, McNeely MDD. The influence of an expert system for test ordering and interpretation on laboratory investigations. Clinical Chemistry 1999;45:1168-1175.
27. Zaat JOM. De macht der gewoonten: Over de huisarts en zijn laboratorium onderzoek [Thesis]. Amsterdam: Free University Amsterdam; 1991 *(On the General Practitioner and his laboratory-test ordering. In Dutch, English Summary).*
28. Lomas J, Anderson GM, Domnick-Pierre K, Vayda E, Enkin MW, Hannah WJ. Do practice guidelines guide practice? The effect of a consensus statement on the practice of physicians. New England Journal of Medicine 1989;321:1311-1315.
29. Hayward RSA. Clinical practice guidelines on trial. CMAJ 1997;156:1725-27.
30. Woolf SH. Practice guidelines: a new reality in medicine, III: impact on patient care. Archives of Internal Medicine 1993;153:2646-55.
31. Grimshaw JM, Russell IT. Effect of clinical guidelines on medical practice: A systematic review of rigorous evaluations. The Lancet 1993;342:1317-1322.
32. McColl A, Smith H, White P, Field J. General practitioners' perceptions of the route to evidence based medicine: a questionnaire survey. British Medical Journal 1998;316:361-365.
33. Tierney WM, Overhage JM, Takesue BY, Harris LE, Murray MD, Vargo DL, et al. Computerizing guidelines to improve care and patient outcomes: the example of heart failure. Journal of the American Medical Informatics Association 1995;2:316-322.
34. Tierney WM, Miller MD, McDonald CJ. The effect on test ordering of informing physicians of the charges for outpatient diagnostic tests. New England Journal of Medicine 1990;322:1499-1504.
35. Musen MA, Rohn JA, Fagan LM, Shortliffe EH. Knowledge engineering for a clinical trial advice system: uncovering errors in protocol specification. Bulletin of Cancer 1987;74:291-296.
36. McDonald CJ, Overhage JM. Guidelines you can follow and trust: An ideal and an example. Journal of the American Medical Association 1994;271:872-873.
37. Shiffman RN. Towards effective implementation of a pediatric asthma guideline: Integration of decision support and clinical workflow support. In: Ozbolt JG, editor. Proceedings of the 18th annual Symposium on Computer Applications in Medical Care; 1994: Philadelphia: Hanley and Belfus Inc; 1994. p. 797-801.

38. Shiffman RN. Clinical guidelines in medical practice. Journal of Medical Practice Management 1993;9:70-74.
39. Winkens RAG, Pop P, Grol RPTM. Effect of feedback on test ordering behavior of general practitioners. British Medical Journal 1992;304:1093-1097.
40. Pop P, Winkens RAG. A diagnostic centre for general practitioners: results of individual feedback on diagnostic actions. Journal of the Royal College of General Practitioners 1989;39:507-8.
41. Winkens RAG, Pop P, Grol RP, Bugter-Maessen AM, Kester AD, Beusmans GH, et al. Effects of routine individual feedback over nine years on general practitioners' requests for tests. British Medical Journal 1996;24:490.
42. Winkens RA, Bugter-Maessen AM, Grol RP, Kester AD, Beusmans GH, Knottnerus JA. Randomised controlled trial of routine individual feedback to improve rationality and reduce numbers of test requests. The Lancet 1995;25:498-502.
43. Bugter-Maessen AM, Winkens RA, Grol RP, Knottnerus JA, Kester AD, Beusmans GH, et al. Factors predicting differences among general practitioners in test ordering behaviour and in the response to feedback on test requests. Family Practice 1996;13:254-8.
44. Smithuis LOMJ, Van Geldrop WJ, Lucassen PLBJ. Beperking van het laboratoriumonderzoek door een probleemgeoriënteerd aanvraagformulier. Een partiële implementatie van NHG-standaarden. Huisarts Wet 1994;37:464-66 *(Reducing test ordering by introducing a problem-oriented order form. Partial implementation of the guidelines of the Dutch Colleges of General Practitioners. In Dutch, English abstract).*
45. Van Gend JMWA, Van Pelt J, Cleef THM, Mangnus TM, Muris JWM. Kwaliteitsverbeteringsproject "laboratoriumdiagnostiek door huisartsen" leidt tot aanzienlijke reductie van het aantal laboratoriumanalyses. Ned Tijdschr Geneeskd 1996;140:495-500 *(The quality improvement project "laboratory test ordering by general practitioners", reduces the number of test ordered. In Dutch, English abstract).*
46. Van Geldrop WJ, Lucassen PLBJ, Smithuis LOMJ. Een probleemgeoriënteerd aanvraagformulier voor laboratoriumonderzoek. Effecten op het aanvraaggedrag van huisartsen. Huisarts Wet 1992;35:192-196 (*A problem-oriented test order form. Impact on test-ordering behavior of general practitioners).*
47. Winkens RAG. Improving test ordering in general practice. The effects of individual feedback. Maastricht: Rijks Universiteit Limburg; 1994.

48. Grol R, Dalhuijsen J, Thomas S, Veld C, Rutten G, Mokkink H. Attributes of clinical guidelines that influence use of guidelines in general practice: observational study. British Medical Journal 1998;317:858-861.
49. Langley C, Faulkner A, Watkins C, Gray S, Harvey I. Use of guidelines in primary care--practitioners' perspectives. Family Practice 1998;15:105-11.
50. Grol R, Wensing M. Implementation of quality assurance and medical audit: general practitioners' perceived obstacles and requirements. British Journal of General Practice 1995;45:548-52.

Chapter 2

Analysis of the Practice Guidelines of the Dutch College of General Practitioners with Respect to the Use of Blood Tests

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2.1 Abstract

Objective: To determine the consistency among the practice guidelines of the Dutch College of General Practitioners with respect to the use of blood tests.

Methods: We evaluated 64 practice guidelines of the Dutch College of General Practitioners. For each of the guidelines, we analyzed each sentence that contained a reference to a blood test to determine the clinical situation in which the test should be performed (*the indication*), and to determine the tests that should be performed in that situation (*the recommended test*). An *incomplete recommendation* refers to a guideline that mentioned a blood test, but did not identify the indication for that test. An *inconsistency* refers to the situation in which one guideline recommended a certain test for a given indication whereas another guideline mentioned the same indication but did not recommend the same test.

Results: Twenty-seven practice guidelines mentioned blood tests. Of these, three explicitly recommended *not* to request blood tests. Five guidelines contained incomplete recommendations. We encountered two inconsistencies among the guidelines. Twenty-three guidelines mentioned blood tests and allowed us to identify indications and recommended tests.

Conclusion: The identification of indications and recommended tests allows evaluation of consistency among practice guidelines. Although some incomplete recommendations and inconsistencies were discovered, the majority of the guidelines provide clear and unambiguous recommendations for blood test ordering in primary care.

Keywords: Family Practice, Practice Guidelines (standards), Diagnostic Tests, Laboratories.

2.2 Introduction

To deal with the rapidly expanding amount of medical knowledge, guidelines increasingly are viewed as a mechanism for distributing knowledge to practitioners (1, 2). Governmental agencies and professional organizations are developing clinical practice guidelines. In The Netherlands, the Dutch College of General Practitioners issues guidelines for the general practitioner. These guidelines are published regularly in "Huisarts en Wetenschap", the journal of the Dutch College of General Practitioners. These guidelines assist general practitioners in dealing with specific clinical conditions in a primary care setting.

A number of studies have shown that the existence of guidelines does not necessarily lead to the use of these guidelines by physicians. Even when authoritative guidelines are available, changing the behavior of physicians has proven to be difficult (3, 4). Investigators acknowledge that the implementation of guidelines constitutes an important research area that has to be addressed (5).

One mechanism for implementing guidelines is using information technology to develop decision support systems based on guidelines. Decision support systems based on guidelines may focus on supporting a single guideline for a particular disease, e.g., heart failure, asthma, or diabetes. The objective of the system is to help the practitioner in the management of the patient with a particular disease using the corresponding guideline. Such a system typically covers several aspects of care; these systems provide recommendations for diagnostic investigations, selection of treatment, and follow-up. In this approach, the paper-based guidelines are replaced by electronic guidelines. Past experience, however, has shown that researchers developing decision support systems based on a guideline may encounter significant problems such as inconsistencies in the guideline, inaccurate or incomplete descriptions of terms, ambiguity, or incompleteness (6-11). This change from paper guidelines to a decision support system, therefore, requires an extensive analysis of the content of the guidelines.

Unlike systems that focus on a single guideline, we focus on the collection of guidelines issued by the Dutch College of General Practitioners. Discrepancies and inconsistencies among different guidelines that are dealing with similar issues may further aggravate the problems encountered by developers of systems based on individual guidelines. Several guidelines, for example, may refer to the same diagnostic investigation, disease, or treatment. The guidelines, however, not necessarily agree on the recommended course of action. Given the procedures, by which these guidelines are developed, such inconsistencies are possible; the development of a guideline is not just a scientific endeavor, but the human factor plays an important role (12).

The procedure of creating a guideline consists of four stages (12). The first stage involves the selection of appropriate topics for new guidelines by an independent advisory board. The guidelines are intended for use by general practitioners; the topics selected and the levels of detail thus reflect practice in primary care. Although criteria for selecting topics are articulated, the process of selecting topics is partly subjective. In the second stage, a small taskforce consisting of four to eight general practitioners with special interest in and expertise on the topic of that guideline prepare a draft. This draft is based on a review of the available literature and current medical practice. As a result, the draft reflects not only scientific evidence, but also the consensus in the taskforce with respect to appropriate medical practice in primary care. In the third stage, this draft is peer reviewed by a random sample of 50 Dutch general practitioners and a number of specialists. The fourth and final stage involves the authorization of the guideline by a board consisting of leading general practitioners including the chairs of the university departments of General Practice. After authorization, the guideline is published in the journal of the Dutch general practitioners. This publication consists of three parts: a brief, algorithmic summary of the guideline that focuses on the decisions the general practitioner has to make; a more detailed description of the guideline itself; and a scientific justification of the guideline. The brief, algorithmic summary of the guideline is also distributed as separate card that can be used during consultations. In addition, teaching material is prepared that can be used for continuing medical education.

Although the available scientific evidence plays an important role, the Dutch College of General Practitioners acknowledges that the guidelines are, to a varying degree, dependent on subjective opinions of individuals involved in the creation of that guideline (12). Each guideline is based on arguments of the individual members of the taskforce and subsequent reviewers. For each guideline, however, different general practitioners participate in the taskforce. The process of developing guidelines, therefore, does not guarantee consistency. In order to develop a decision support system that provides the general practitioner with recommendations based on all the available guidelines, these guidelines need to be analyzed and evaluated for inconsistencies within an individual guideline and for inconsistencies among guidelines. In order to focus the analysis, we restrict ourselves to the recommendations for blood tests. The choice for recommendations for blood tests is based on previous Dutch research.

Requesting blood tests is an important aspect of the health care delivered by the general practitioner in The Netherlands. Although lower than in many other European countries (13), about four percent of the patients' encounters with Dutch general practitioners result in the physician requesting blood tests (14), physicians' use of blood tests, however, is not always appropriate (1, 15-19). Dutch investigators report a lack of general practitioners' knowledge concerning the indications for blood tests leading to inappropriate and inadequate use of diagnostic tests (20). The need to improve the use of blood tests, however, is not limited to The Netherlands. Other investigators argue that improving the quality of blood test ordering deserves attention (21-23).

The objective of this study is to evaluate the guidelines of the Dutch College of General Practitioners with respect to the ordering of blood tests. We want to determine whether these guidelines provide a consistent base for the development of a decision support system for blood test ordering.

2.3 Methods

Until January 1st 1998, the Dutch College of General Practitioners had published in total 64 guidelines. The College regularly updates the guidelines. We analyzed the most recent version of each guideline that was available on January 1st 1998. Changes in the guidelines after this date are not included in this study.

For each of the guidelines, we analyzed each sentence to determine whether that sentence contained a reference to a blood test. If the sentence contained a reference to blood tests, we determined the clinical situation in which the test should be performed (*the indication*), and determined the tests that should be performed in that situation (*the recommended test*). An *incomplete recommendation* refers to a guideline that mentioned a blood test, but did not identify in the guideline the indication for that test, or a guideline that mentioned an indication for blood tests but did not provide a further specification of the recommended blood tests. The notion of an incomplete recommendation is restricted to particular recommendations; we do not determine whether the total set of recommendations is "complete" in the sense that the set covers all indications in primary care.

After we identified the indications and recommended tests in all guidelines, we checked – for each indication in each guideline – whether another guideline recommended another test for the same indication. An *inconsistency* refers to the situation in which one guideline recommended a certain test for a given indication whereas another guideline mentioned the same indication but did not recommend the same test.

2.4 Results

Of the sixty-four guidelines, twenty-seven guidelines contained at least one sentence that included a reference to blood tests. Of the twenty-seven guidelines that mentioned blood tests, three explicitly recommended *not* to request blood tests. The guideline "Sinusitis" states that sinusitis itself is not an indication for an ESR (24), the guideline "Depression" states that depression itself is not an indication for TSH or T4 (25), and the guideline

"Blood tests and liver disease" states that infectious mononucleosis itself is not an indication for liver function tests (26).

2.4.1 Incomplete Recommendations

Of the twenty-seven guidelines containing at least one sentence that included a reference to blood tests, five guidelines contained incomplete recommendations; that is, the guideline mentions a blood test, but does not describe the indication. The guideline "Imminent miscarriage" mentions a possible Hb but does not specify which patients are eligible (27). The guideline "Children with fever" states that blood tests are seldom indicated; when blood test are indicated, and which tests should be requested, however, is not specified (28). The guideline "Problematic alcohol consumption" identifies abnormal values of gamma-GT, ASAT and ALAT as possible indicators of excessive alcohol abuse, but does not describe if and when these tests should be performed (29). The guideline "Intrauterine device" mentions the possibility of elevated ESR and leukocytosis, but does not specify if and when these tests should be performed (30). The guideline "Acne vulgaris" states that, prior to treatment with isotretinoin, liver and kidney functions should be evaluated; the guideline, however, provides no further specification of which tests should be done (31).

2.4.2 Indications and Recommended Tests

Of the 64 guidelines, 23 guidelines mentioned blood tests and allowed us to identify the indication for those tests (26, 31-52). We distinguish five different categories of indications. The first category of indications describes clinical situations in which the general practitioner considers a diagnosis, the *working diagnosis*. This working diagnosis is the most probable diagnosis based on the patient's medical history and/or physical examination.

The physician subsequently uses the laboratory tests to support or refute that diagnosis. In total, the guidelines mention 18 working diagnoses. Table 1 shows the working diagnosis, the recommended tests, and the guideline that makes the recommendation. In some cases, abnormal results of initial tests

should be followed by additional investigations; for example, an abnormal value for TSH should be followed by a test for free T4.

Table 1: Recommended test(s) per working diagnosis.

Working diagnosis	Recommended test(s)	Guideline
Alcohol-induced hepatitis	ALAT, Gamma-GT	Zaat et al, 1992 (26)
Allergic Asthma (Adults)	Phadiatop[1], RAST[2]	Geijer et al. 1997 (40)
Allergic Asthma (Children)	Phadiatop[3] RAST[4]	Dirksen et al, 1998 (39)
Allergic rhinitis	Phadiatop[1]	Crobach et al, 1995 (34)
Diabetes mellitus	Glucose	Cromme et al, 1989 (35)
Drug-induced liver damage	ALAT, Gamma-GT	Zaat et al, 1992 (26)
Hepatitis A	Anti-HAV-IgM, Anti-HAV-IgG	Zaat et al, 1992 (26)
Hepatitis B	HbsAG, ALAT, HBc-AS	Zaat et al, 1992 (26)
Hepatitis C	HCV	Zaat et al, 1992 (26)
Hypercholesterolemia	Cholesterol	Van Binsbergen et al, 1991 (49)
Hyperthyroidism	TSH[5]	Pop et al, 1993 (45)
Hypothyroidism	TSH[5]	Pop et al, 1993 (45)
Infectious mononucleosis	WBC count, WBC differentiation[6]	Balder et al, 1990 (33)
Cirrhosis of the liver	Albumin	Zaat et al, 1992 (26)
Pelvic inflammatory disease	ESR	Dekker et al, 1995 (37)
Prostate cancer	PSA	Klomp et al, 1994 (41)
Rheumatoid arthritis	Rheumatoid factors	Schuurman et al, 1994 (47)
Septic arthritis	ESR	Bakker et al,1990 (32)

Note: ALAT indicates alanine aminotransferase; Gamma-GT, gamma-glutamyltransferase; Phadiatop is a blood test for screening the most common inhalation allergens; RAST, radioallergosorbenttest; anti-HAV-IgM/IgG, antibody to hepatitis A virus immunoglobulin G; HbsAg, hepatitis B surface antigen; HBcAg, hepatitis core antigen; HCV, hepatitis C virus; TSH, thyroid-stimulating hormone; WBC, white blood cell (leukocyte) count, ESR, erytrocyte sedimentation rate; PSA, prostate specific antigen.

[1] If Phadiatop results are positive, RAST-dust mite and, if cat or dog is present as domestic animals, RAST-cat or RAST-dog.
[2] If medical history indicates, RAST-horse ore RAST- rodents .
[3] If Phadiatop results are positive, RAST-dust mite and, if cat, dog or horse is present as a domestic animals, RAST-cat, RAST-dog, or RAST-horse.
[4] If medical history indicates, RAST-rodents.
[5] If TSH results are positive, free thyroxine (T4) measurement.
[6] If WBC findings and differentiation are positive, Paul Bunnell (a test to determine the presence of infectious mononucleosis).

The second category of indications describes clinical situations in which the general practitioner has established a diagnosis, and uses the laboratory to investigate *underlying pathology* that could cause the disease. The crucial difference with the category working diagnosis is that in case of underlying pathology the guideline requires that the physicians has already established the presence of a specific diagnosis. Given the presence of this specific diagnosis, the guideline specifies the evaluation of possible causes of that diagnosis. In

total, the guidelines mention 10 diagnoses in which underlying pathology needs to be explored. Table 2 shows the diagnoses, the suspected underlying pathology, the recommended tests, and the guideline that makes that recommendation. For example, when the diagnosis transient ischaemic attack (TIA) has been established, the guideline TIA recommends that an ESR and glucose be requested to explore arteritis temporalis and diabetes mellitus as underlying causes of the TIA.

Table 2: Per diagnosis, advised test(s) for underlying pathology.

Diagnosis	Underlying disease	Advised test(s)	Guideline
Angina pectoris	Anemia	Hb	Rutten et al, 1994 (46)
Angina pectoris	Hyperthyroidism	TSH	Rutten et al, 1994 (46)
Angina pectoris	Diabetes mellitus	Glucose	Rutten et al, 1994 (46)
Angina pectoris	Hypercholesterolemia	Cholesterol	Rutten et al, 1994 (46)
Dementia	Infectious diseases	ESR	De Bruyne et al, 1991 (36)
Dementia	Anemia	Hb, MCV, Ht	De Bruyne et al, 1991 (36)
Dementia	Kidney dysfunction	Creatinine	De Bruyne et al, 1991 (36)
Dementia	Thyroid disorder	TSH	De Bruyne et al, 1991 (36)
Heart failure	Anemia	Hb	Walma et al, 1995 (51)
Heart failure	Hyperthyroidism	TSH	Walma et al, 1995 (51)
Hypercholesterolemia	Hypothyroidism	TSH	Van Binsbergen et al, 1991 (49)
Hypercholesterolemia	Diabetes mellitus	Glucose	Van Binsbergen et al, 1991 (49)
Hypercholesterolemia	Alcohol abuse	ALAT, gamma-GT	Van Binsbergen et al, 1991 (49)
Hypercholesterolemia	Liver disease	ALAT, gamma-GT	Van Binsbergen et al, 1991 (49)
Hypertension	Primary hyperaldosteronism	K	Van Binsbergen et al, 1991 (49)
Icterus	Prehepatic/posthepatic icterus	ALAT, Total Bilirubine, Gamma-GT	Zaat et al, 1992 (26)
Icterus	Hemolytic anemia	ALAT, Total Bilirubine, gamma-GT, Hb	Zaat et al, 1992 (26)
Icterus gravis neonatorum	Pathologic neonatal icterus	Total Bilirubine	Zaat et al, 1992 (26)
Iron therapy-resistant anemia	Hemoglobinopathia in Negroid, Mediterranean and Southeast Asian woman	Hb, MCV, Serum-ferritin	Oldenziel et al, 1993 (44)
TIA	Arteritis temporalis	ESR	Van Binsbergen et al, 1995 (50)
TIA	Hypercholesterolemia	Cholesterol	Van Binsbergen et al, 1995 (50)
TIA	Diabetes mellitus	Glucose	Van Binsbergen et al, 1995 (50)
Ulcus cruris	Diabetes mellitus	Glucose	Schweitzer et al, 1991 (48)
Vague complaints	Infectious diseases	ESR	Dinant et al, 1994 (38)
Vague complaints	Anemia	Hb	Dinant et al, 1994 (38)
Vague complaints	Diabetes mellitus	Glucose	Dinant et al, 1994 (38)
Vague complaints	Hyperthyroidism	TSH	Dinant et al, 1994 (38)

Note: Hb indicates hemoglobin; TSH, thyroid-stimulating hormone; ESR, erythrocyte sedimentation rate; MCV, mean cell volume; Ht, hematocrit; ALAT, alanine aminotranferase; gamma-GT, gamma-glutamyltranferase; K, potassium

The third category of indications involves *monitoring the course of a disease.* The physician has established the diagnosis, and is monitoring the progression of the disease. In total, six guidelines mention diagnoses that can be monitored. Table 3 shows the established diagnosis, the tests recommended to monitor that condition, and the guideline that makes that recommendation. For example, to monitor diabetes mellitus, the guideline *diabetes mellitus* recommends that the physician obtains a glucose measurement every three months, and cholesterol and creatinine annually.

Table 3: Per diagnosis, recommended test(s) for monitoring course of disease.

Diagnosis	Recommended test(s)	Guideline
Diabetes mellitus	Glucose, Cholesterol, Creatinine[1]	Cromme et al, 1989 (35)
Hepatitis A	ALAT[2]	Zaat et al, 1992 (26)
Hepatitis B	ALAT, HBsAg, HBeAg[3]	Zaat et al, 1992 (26)
Hypercholesterolemia	Cholesterol[4]	Van Binsbergen et al, 1991 (49)
Hyperthyroidism	Free T4[5]	Pop et al, 1993 (45)
Hypothyroidism	TSH, Free T4[6]	Pop et al, 1993 (45)
Pregnancy	Hb, Blood type, TPHA, HBsAg, IgG antirubella[7]	Oldenziel et al, 1993 (44)
Rheumatoid arthritis	Hb, MCV[8]	Schuurman et al, 1994 (47)

Note: ALAT indicates alanine aminotransferase; HBsAg, hepatitis B surface antigen; HBeAg, hepatitis B early antigen; T4, thyroxine; TSH, thyroid-stimulating hormone; Hb, hemoglobin; TPHA, *Treponema pallidum* hemagglutination; IgG, immunoglobulin G; MCV, mean cell volume.

[1] Fasting glucose every three months; cholesterol and creatinine once a year.
[2] ALAT every three weeks.
[3] HBsAg and HbeAg after four and eight weeks; ALAT every three weeks
[4] Cholesterol measurement six months after the start of therapy, followed by yearly evaluation.
[5] Free T4 measurement every six weeks until euthyroidism is achieved; subsequently ,every three months.
[6] Free T4 measurement six weeks after every change of medication. If euthyroidism is achieved every three months during the first year; subsequently, once a year.
[7] IgG antirubella measurement at the first pregnancy; Hb, HbsAg and TPHA every pregnancy.
[8] Hb measurement twice a year; MCV measurement only in case of positive Hb results.

The fourth category of indications describes situations in which blood tests are used to *select appropriate treatment*. In these situations, the physician has established the diagnosis, and the blood tests are used to identify factors that have a direct bearing on the choice of subsequent treatment. Based on the results of these blood tests, the guideline specifies the treatment of choice. In total, seven guidelines identify blood tests that are used to select treatment. Table 4 shows the established diagnosis, the factor that is identified, the recommended tests, and the guideline that makes the recommendation. For example, the guideline "Cholesterol" recommends in case of hypercholesterolemia the measurement of high-density lipoprotein cholesterol and triglycerides to identify lipid metabolism disorder, in order to select the right therapy.

Table 4: Per diagnosis, recommended test(s) for selecting appropriate treatment.

Diagnosis	Factor	Recommended test(s)	Guideline
Constitutional eczema	Food allergy	RAST-food mix	Lucassen et al, 1995 (42)
Food hypersensitivity in infants	Serious reaction at food provocation	RAST 5	Lucassen et al, 1995 (42)
Hypercholesterolemia	Elevated triglycerides	Triglycerides	Van Binsbergen et al, 1991 (49)
Hypercholesterolemia	Elevated HDL	HDL-cholesterol	Van Binsbergen et al, 1991 (49)
Hypertension	With risk factors	Glucose, Cholesterol, Creatinine	Van Binsbergen et al, 1991 (49)
Impeded urination in elderly males	Kidney dysfunction	Creatinine	Klomp et al, 1994 (41)
Vaginal bleeding	Anemia	Hb	Meijer et al, 1992 (43)

Note: RAST indicates radioallergosorbent test; HDL, high-density lipoprotein; Hb, hemoglobin

The fifth category of indications describes situations in which blood tests are used to *monitor the side effects of drugs*. The guidelines state that for certain drugs, the physician should monitor the patient for potential side effects of the drugs. In some instances, this requires periodic blood tests. The results of the blood tests might lead to modification of prescribe dosages or termination of the treatment with that drug. In total, four guidelines identify blood tests that need to be performed to monitor side effects of drugs. Table 5 shows the drugs involved, the side effects to be monitored, the recommended tests, the frequency of performing these tests, and the guideline that makes the recommendation. For example, the guideline "Acne vulgaris" states that one month after starting treatment with isotretinoin, cholesterol and triglycerides need to be measured and subsequently every 3 month.

Table 5: Recommended test(s) in monitoring side effects of therapy.

Therapy	Side-effect	Recommended test(s)	Guideline
Roaccutaan	Hyperlipidemia	Cholesterol, Triglycerides[1]	Blom et al, 1991 (31)
HMG -coenzyme inhibitors	Liver dysfunction	ALAT[2]	Van Binsbergen et al, 1991l (49)
HMG -coenzyme inhibitors	Muscular pain	CK[3]	Van Binsbergen et al, 1991l (49)
Ace-inhibitors, digoxine, diuretics	Not specified	K, Creatinine, Na[4]	Walma et al, 1995 (51)
Sulfasalazine	Anemia	Hb[5]	Schuurman et al, 1994 (47)
Sulfasalazine	Liverdysfunction	ALAT, Gamma-GT[5]	Schuurman et al, 1994 (47)
Sulfasalazine	Agranulocytosis	Thrombocytes, WBC, WBC-differentation[5]	Schuurman et al, 1994 (47)
Sulfasalazine	Not specified	Creatinine[5]	Schuurman et al, 1994 (47)

Note: HMG-coenzyme inhibitors indicates hydroxymethylglutaryl-CoA reductase inhibitors; ALAT, alanine aminotransferase; CK, creatinine kinase; K, potassium; NA, sodium; Hb, hemoglobin; gamma-GT, gamma-glutamyltransferase; WBC, white blood cell (leukocyte) count.

[1] Baseline measurement of triglycerides at the start of treatment; subsequently, after four weeks, followed by evaluation every three months.
[2] Baseline measurement of ALAT at the start of treatment; subsequently, after four weeks.
[3] Creatine kinase after four weeks of therapy (only when the patient complaints of muscular pain).
[4] Sodium measurement once every six months.
[5] Hemoglobin measurement every two weeks during the first three month of therapy; subsequently, every month.

2.4.3 Inconsistencies

We encountered two inconsistencies among the guidelines. The guideline "Angina pectoris" (46) showed an inconsistency with the guideline "Disorder of the thyroid gland" (45). The guideline "Shoulder complaints" (32) showed an inconsistency with the guideline "Rheumatoid arthritis" (47).

According to the guideline "Angina pectoris", the general practitioner should in case of angina pectoris in combination with tachycardia request TSH to evaluate

hyperthyroidism. The guideline "Disorder of the thyroid gland" describes when a TSH should be obtained; patients with angina pectoris and tachycardia, however, are not mentioned.

The guideline "Shoulder complaints" states that insufficient effect of initial treatment is a reason for blood tests; an elevated ESR is an indicator for rheumatoid or septic arthritis. In the guideline "Rheumatoid arthritis", however, the list of recommended tests for excluding or confirming rheumatoid arthritis does not include ESR.

2.5 Discussion

The objective of this study was to identify in all guidelines issued by Dutch College of General Practitioners the specific recommendations for using the laboratory and to analyze these recommendations for inconsistencies. The underlying reason for such an analysis was the desire to build a decision support system that would help general practitioners in using these guidelines.

2.5.1 Guidelines

Our study shows that the guidelines contain specific and detailed recommendations for ordering blood tests. Given the fact that previous studies have reported a lack of general practitioners' knowledge concerning indications for tests (18, 20), the guidelines could provide needed support. These recommendations, however, are scattered throughout many different guidelines (a total of 27 out of the 64 practice guidelines). In addition, the guidelines may overlap. For example, the guideline "Problematic alcohol consumption" states that increased levels of gamma-GT, ASAT and ALAT are possible indicators of excessive alcohol abuse; the guideline does not describe if or when these tests should be performed. The guideline "Blood tests and liver disease" specifies that if the practitioner suspects alcohol-induced hepatitis, an ALAT and Gamma-GT should be performed; the ASAT is in this guideline considered redundant. We conclude that the currently available

paper-based guidelines require the general practitioner to spend time and effort to locate and interpret the recommendations for blood tests.

A total of two inconsistencies were found among the guidelines with respect to the use of the laboratory. A possible explanation for these inconsistencies could be the fact that, although the guidelines are revised regularly, not all guidelines are revised at the same time. As a result, one guideline may already reflect changed medical understanding, whereas another, possibly due for revision in the near future, does not yet reflect this change. Given that inconsistencies were found, we recommend that organizations that maintain a set of guidelines should make available to physicians a list of known inconsistencies among those guidelines.

Our analysis shows that, with respect to the use of the laboratory tests, five guidelines contained incomplete recommendations. Ambiguity or lack of clarity in guidelines could create uncertainty on the part of the general practitioner that in turn could stimulate the ordering of unnecessary blood tests. Guideline developers should therefore, avoid incomplete recommendations in guidelines. Twenty-three guidelines, however, did contain well-defined and specific recommendations for the use of the laboratory. Given that other investigators have reported a lack of knowledge about test ordering, we believe that applying the guidelines in general practice would result in improved test ordering by general practitioners.

2.5.2 Decision Support System

From the perspective of Medical Informatics, the objective of our study was to identify the specific recommendations for using the laboratory, and analyze them for inconsistencies. From this perspective we conclude that the guidelines contain concrete and specific recommendations, and that only few inconsistencies were found. Moreover, the study shows that identifying the *indication* for requesting blood test is one possible method for analyzing the guidelines. The indication for blood tests is the specific question of the physician to which obtaining the test will provide an (partial) answer. We conclude that the recommendations for blood tests in the guidelines of the

Dutch College of General Practitioners are focused on describing what tests are necessary in the context of a given indication.

For researchers in Medical Informatics, this notion of the indication as the physician's question has significant consequences for designing a decision support system. Given the concept of the indication, the designer faces a choice. The first alternative is, given the patient's symptoms, that the system identifies the indication for blood tests. The second alternative is, given the indication, that the systems selects the appropriate tests. For the general practitioner, these two approaches will result in two very different systems. If the objective is to support the identification of the indication, the decision support system will request detailed information about the patient's condition. Based on these findings, the system will generate possible indications, select among these, and prepare a recommendation. If the objective of the system is to select the appropriate test given the indication, the decision support system will start asking the physician questions about his or her indication; the translation of the patient's condition to a specific indication is left to the general practitioner. The system builder thus has to determine whether the decision support is based on the patient's symptoms or on the physician's indications.

We have decided to build a system that requests from the physician the indication. As a result, the system is driven by questions related to the objectives of the physician. The system does not ask detailed questions about the symptoms or complaints of the patient. The downside of this approach is that the system does not support the physician in establishing the appropriate indication based on the complaints of the patient. This decision to leave the identification of the initial working diagnosis to the general practitioner is not only based on the fact that the guidelines provide recommendations on the level of indication. We also believe that especially physicians are able to translate the often-complex presentation of patients' complaints to well-defined indications. In addition, a general practitioner in The Netherlands sees a very different patient population when compared to a specialist working in a hospital since the prevalence of diseases is different. The patient's complaints presented in general practice might well result in selecting a different working diagnosis when compared to a hospital setting. Computers are only able to deal with those parts of the patient-physician encounter that can be translated

to objective facts and numbers; as a result, decision support systems can only deal with a very limited segment of reality. Other investigators have lamented the fact that decision support systems tend to ignore the intellect of physicians (53), and leave the practitioner with a sense of losing control (54). We believe that in the area of the initial interpretation of the symptoms of the patient the role of a decision support system should be very limited.

Further research will have to show whether decision support based on the guidelines is acceptable and effective.

2.6 References

1. Wong ET, Lincoln TL. Ready! Fire! ...Aim. Journal of the American Medical Association 1983;250(18):2510-2513.
2. Kelly JT. Role of clinical practice guidelines and clinical profiling in facilitating optimal aboratory use. Clinical Chemistry 1995;41:1234-1236.
3. Lomas J, Anderson GM, Domnick-Pierre K, Vayda E, Enkin MW, Hannah WJ. Do practice guidelines guide practice? The effect of a consensus statement on the practice of physicians. New England Journal of Medicine 1989;321:1311-1315.
4. Grimshaw JM, Russell IT. Effect of clinical guidelines on medical practice: A systematic review of rigorous evaluations. The Lancet 1993;342:1317-1322.
5. Lomas J. Words without action? The production, dissemination and impact of consensus recommendations. Annual Review of Public Health 1991;12:41-65.
6. Tierney WM, Overhage JM, Takesue BY, Harris LE, Murray MD, Vargo DL, et al. Computerizing guidelines to improve care and patient outcomes: the example of heart failure. Journal of the American Medical Informatics Association 1995;2:316-322.
7. Tierney WM, Miller MD, McDonald CJ. The effect on test ordering of informing physicians of the charges for outpatient diagnostic tests. New England Journal of Medicine 1990;322:1499-1504.
8. Musen MA, Rohn JA, Fagan LM, Shortliffe EH. Knowledge engineering for a clinical trial advice system: uncovering errors in protocol specification. Bulletin of Cancer 1987;74:291-296.
9. McDonald CJ, Overhage JM. Guidelines you can follow and trust: An ideal and an example. Journal of the American Medical Association 1994;271:872-873.
10. Shiffman RN. Towards effective implementation of a pediatric asthma guideline: Integration of decision support and clinical workflow support. In: Ozbolt JG, editor. Proceedings of the 18th annual Symposium on Computer Applications in Medical Care; 1994: Philadelphia: Hanley and Belfus Inc; 1994. p. 797-801.
11. Shiffman RN. Clinical guidelines in medical practice. Journal of Medical Practice Management 1993;9:70-74.

12. Thomas S. Standard setting in the Netherlands: impact of the human factor on guideline development. British Journal of General Practice 1994;44:242-3.
13. Leurquin P, Van Casteren V, De Maeseneer J. Use of blood tests in general practice: A collaborative study in eight European countries. British Journal of General Practice 1995;45:21-25.
14. Kluijt I, Zaat JOM, Van der Velden J, van Eijk JTM, Schellevis FG. Voor een prikje: Huisarts en bloedonderzoek. Huisarts en Wetenschap 1991;34:67-71 *(The general practitioner and bloodtests. In Dutch, English abstract.).*
15. Kassirer JP. Diagnostic reasoning. Annals of Internal Medicine 1989;110:893-900.
16. Kassirer JP. Our stubborn quest for diagnostic certainty. New England Journal of Medicine 1989;320(22):1489-1491.
17. Ornstein SM, Markert GP, Johnson AH, Rust PF, Afrin LB. The effect of physician personality on laboratory test ordering for hypertensive patients. Medical Care 1988;26(6):536-543.
18. Axt-Adam P, Van der Wouden JC, Van der Does E. Influencing behavior of physicians ordering laboratory tests: A literature study. Medical Care 1993;31:784-794.
19. Eisenberg JM, Nicklin D. Use of diagnostic services by physicians in community practice. Medical Care 1981;19(3):297-309.
20. Zaat JOM. De macht der gewoonten: Over de huisarts en zijn laboratorium onderzoek [Thesis]. Amsterdam: Free University Amsterdam; 1991 *(On the General Practitioner and his laboratory-test ordering. In Dutch, English Summary).*
21. Van Walraven C, Naylor CD. Do we know what inappropriate laboratory utilization is? A systematic review of laboratory clinical audits. Journal of the American Medical Association 1998;280:550-558.
22. Van Walraven C, Goel V, Chan B. Effect of population-based interventions on laboratory utilization: a time-series analysis. Journal of the American Medical Association 1998;280:2028-33.
23. Solomon DH, Hashimoto H, Daltroy L, Liang MH. Techniques to improve physicians' use of diagnostic tests. Journal of the American Medical Association 1998;280:2020-2027.
24. De Bock GH, Van Duijn NP, Dagnelie CF, Geijer RMM, Van de Hell RJ, Labots-Vogelesang SM, et al. NHG-Standaard Sinusitis. Huisarts en Wetenschap 1993;36:255-7 *(Dutch College of General Practitioners - Guideline sinusitis).*
25. Van Marwijk HWJ, Grundmeijer HGLM, Brueren MM, Sigling HO, Stolk J, Van Gelderen MG, et al. NHG-Standaard depressie. Huisarts en

Wetenschap 1994;37:482-90 *(Dutch College of General Practitioners - Guideline depression).*

26. Zaat JOM, Van Bavel PC, De Bruin HJ, Meijer H, Willemsen JMG, Smeele IJM, et al. NHG-Standaard bloedonderzoek bij verdenking op leveraandoeningen. Huisarts en Wetenschap 1992;35:78-82 *(Dutch College of General Practitioners - Guideline blood test and liverdisease).*
27. Flikweert S, Meijer LJ, De Haan M, Wiersma T. NHG-Standaard miskraam, eerste herziening. Huisarts en Wetenschap 1997;40:661-70 *(Dutch College of General Practitioners - Guideline miscarriage, first revision).*
28. Van der Meulen P, Uitewaal PJM, Boomsma LJ, Van Dijk PA, Hermans AM, Van de Vijver PP, et al. NHG-Standaard kinderen met koorts. Huisarts en Wetenschap 1992;35:512-7 *(Dutch College of General Practitioners - Guideline children with fever).*
29. Van Zutphen W, Van Olst EJ, Cornel M, Willink AE, Hoeksema HL. NHG-Standaard problematisch alcoholgebruik. Huisarts en Wetenschap 1990;33:280-5 *(Dutch College of General Practitioners - Guideline alcohol abuse).*
30. Dukkers van Embden DM, Smeenk RCJ, Treffers JJ, Verblackt HWJ, Westerveld MC, Wibaut P. NHG-Standaard het spiraaltje. Huisarts en Wetenschap 1991;34:89-94 *(Dutch College of General Practitioners - Guideline intra-uterine device).*
31. Blom JJ, Brouwer A, Bruinsma M, Dewachter J, E.J. K, Mesker PJR. NHG-Standaard acne vulgaris. Huisarts en Wetenschap 1991;33:323-6 *(Dutch College of General Practitioners - Guideline acne vulgaris).*
32. Bakker JF, De Jonhg L, Jonquiere M, Mens J, Oosterhuis WW, Poppelaars A, et al. NHG-Standaard schouderklachten. Huisarts en Wetenschap 1990;33:196-202 *(Dutch College of General Practitioners - Guideline shoulder complaints).*
33. Balder FA, Dagnelie CF, De Jong LJ, Kootte H. NHG-Standaard acute keelpijn. Huisarts en Wetenschap 1990;33:323-6 *(Dutch College of General Practitioners - Guideline acute soar throat).*
34. Crobach MJJS, Jung HP, Toorenburg-Beijer B, Van der Wal J, Van Leeuwen JT, Van Puijenbroek EP, et al. NHG-Standaard allergische en hyperreactieve rhinitis. Huisarts en Wetenschap 1995;38:216-27 *(Dutch College of General Practitioners - Guideline allergic and hyperreactive rhinitis).*
35. Cromme PVM, Mulder JD, Rutten GEHM, Zuidweg J, Thomas S. NHG-Standaard diabetes mellitus type II. Huisarts en Wetenschap

1989;32:7-13 *(Dutch College of General Practitioners - Guideline diabetes mellitus type II).*

36. De Bruyne GA, Meyboom-de Jong B, Muskens JB, Veltman MTM, Weijtens JTNM, Wind AW. NHG-Standaard dementiesyndroom. Huisarts en Wetenschap 1991;34:598-607 *(Dutch College of General Practitioners - Guideline dementia).*
37. Dekker JH, Veehof LJG, Heeres PH, Hinloopen RJ, Van den Berg G, Burgers JS. NHG-Standaard pelvic inflammatory disease. Huisarts en Wetenschap 1995;38:310-6 *(Dutch College of General Practitioners - Guideline pelvic inflammatory disease).*
38. Dinant GJ, Van Wijk MAM, Janssens HJEM, Somford RG, De jager CJ, Beusmans GHMI, et al. NHG-Standaard Bloedonderzoek: algemene principes en uitvoering in eigen beheer. Huisarts en Wetenschap 1994;37:202-11 *(Dutch College of General Practitioners - Guideline blood tests: principles).*
39. Dirksen WJ, Geijer RMM, De Haan M, De Koning G, Flikweert S, Kolnaar BGM. NHG-Standaard astma bij kinderen, eerste herziening. Huisarts en Wetenschap 1998;41:130-43 *(Dutch College of General Practitioners - Guideline asthma in children, first revision).*
40. Geijer RMM, Thiadens HA, Smeele IJM, Van der Zwan AAC, Sachs APE, Bottema BJAM, et al. NHG-Standaard COPD en astma bij volwassenen: Diagnostiek. Huisarts en Wetenschap 1997;40:416-29 *(Dutch College of General Practitioners - Guideline COPD and asthma in adults: Diagnosis).*
41. Klomp MLF, Gercama AJ, De Jonge-Wubben JGM, Mulders AHPW, Romeijnders ACM, Rosmalen CFH, et al. NHG-Standaard bemoeilijkte mictie bij oudere mannen, eerste herziening. Huisarts en Wetenschap 1997;40:114-24 *(Dutch College of General Practitioners - Guideline impeded urination in older male , first revision).*
42. Lucassen PLBJ, De Vries-van Oostveen AS, Niebuur HKM, Smeenk RCJ, Stolk PW, Van Moorsel RPM, et al. NHG-Standaard voedselovergevoeligheid bij zuigelingen. Huisarts en Wetenschap 1995;38:178-84 *(Dutch College of General Practitioners - Guideline food allergy in infants).*
43. Meijer LJ, Zwart S, Westerveld MC, Baselier PJAM, Schellekens JWG, Wemekamp H, et al. NHG-Standaard vaginaal bloedverlies. Huisarts en Wetenschap 1992;35:475-81 *(Dutch College of General Practitioners - Guideline vaginal bleeding).*
44. Oldenziel JH, Flikweert S, Giesen PHJ, Lo Fo Wong SH, Vissers GWM, Morshuis RHL, et al. NHG-Standaard zwangerschap en

kraambed. Huisarts en Wetenschap 1993;36:186-96 *(Dutch College of General Practitioners - Guideline pregnancy).*

45. Pop V, Boer AM, Winants Y, Van Bemmel-Uittenhout AM, De Voogd van der Straaten I, Smeele IJM, et al. NHG-Standaard functiestoornissen van de schildklier. Huisarts en Wetenschap 1993;36:143-9 *(Dutch College of General Practitioners - Guideline thyroid disorder).*
46. Rutten FH, Bohnen AM, Hufman P, Bruinsma M, Leerink HJG, Strootman FA, et al. NHG-Standaard angina pectoris. Huisarts en Wetenschap 1994;37:398-406 *(Dutch College of General Practitioners - Guideline angina pectoris).*
47. Schuurman W, Van Alphen JM, Van den Bosch WJHM, Lagro HAHM, Willems D, Romeijnders ACM, et al. NHG-Standaard reumatoïde artritis. Huisarts en Wetenschap 1994;37:248-59 *(Dutch College of General Practitioners - Guideline rheumatoid arthritis).*
48. Schweitzer BPM, Doorenbosch J, Glotzbach R, Barnhoorn K, Breure DP. NHG-Standaard ulcus cruris venosum. Huisarts en Wetenschap 1991;34:270-5 *(Dutch College of General Practitioners - Guideline ulcus cruris).*
49. Van Binsbergen JJ, Brouwer A, Van Drenth BB, Haverkort AFM, Prins A, Van der Weijden T. NHG-Standaard cholesterol. Huisarts en Wetenschap 1991;34:551-7 *(Dutch College of General Practitioners - Guideline cholesterol).*
50. Van Binsbergen JJ, Gelpke JEH, Van Bentum STB, Van der Meer K, Schuling J, Verhoeven S, et al. NHG-Standaard TIA. Huisarts en Wetenschap 1995;38:15-25 *(Dutch College of General Practitioners - Guideline transient ischeamic attack).*
51. Walma EP, Bakx HCA, Besselink RAM, Hamstra PWJ, Hendrick JMA, Kootte JHA, et al. NHG-Standaard hartfalen. Huisarts en Wetenschap 1995;38:471-87 *(Dutch College of General Practitioners - Guideline heart failure).*
52. Walma EP, Grundmeijer HGLM, Thomas S, Prins A, Van den Hoogen JPH, Van der Laan JR. NHG-Standaard hypertensie, eerste herziening. Huisarts en Wetenschap 1997;40(12):598-617 *(Dutch College of General Practitioners - Guideline hypertension, first revision).*
53. Miller RA, Masarie FE. The demise of the Greek oracle model for medical diagnosis systems. Methods of Information in Medicine 1990;29:1-2.
54. Taylor TR. The computer and clinical decision-support systems in primary care. Journal of Family Practice 1990;30((2)):137-140.

Chapter 3

Design of a Decision Support System for Test Ordering in General Practice: Choices and Decisions to Make

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3.1 Abstract

The increased availability of tests in the past years has been accompanied by an increased number of blood tests ordered by general practitioners. Dutch investigators report a lack of general practitioners' knowledge concerning the indications for blood tests leading to inappropriate and inadequate use of diagnostic tests. Taking advantage of the use of electronic patient records by Dutch general practitioners, the authors replaced the traditional paper forms for test ordering by a decision support system. The objective of the decision support system is to change test-ordering behavior.

Designing a system to change test-ordering behavior, however, required the selection of a method to provide support. To study different methods for changing test-ordering behavior, the authors developed two versions of the decision support system BloodLink. The first version, *BloodLink-Restricted*, is based on the notion of restricting the number of choices presented to the general practitioners. The second version, *BloodLink-Guideline*, is based on the guidelines provided by the Dutch College of General Practitioners.

3.2 Introduction

The increased availability of tests in the past years has been accompanied by an increased number of blood tests ordered by general practitioners. In The Netherlands, three to four percent of patients' encounters with the general practitioner result in ordering blood tests by the general practitioner (1). Reasons why general practitioners order blood tests include confirming or excluding a diagnosis, monitoring the progress of a disease, determining the effectiveness of a treatment responding to a specific request of the patient, gaining time to allow nature to cure the disease, or test ordering to reassure the patient (2-8). In the Netherlands, for example, reassuring the patient has been reported as the reason for test ordering in more than 25% of the cases.

General practitioners are taught test ordering when training in hospitals before settling down in general practice (9). Hospital morbidity, however, is different from morbidity patterns in general practice (10-12). Appropriate test ordering panels in hospital setting, therefore, are not always appropriate for primary care. Nevertheless, general practitioners in primary care setting automatically use these test panels, once taught. (13). Uncertainty and the desire not to miss a diagnosis stimulate the use of blood tests (9, 14-18).

Blood tests, as a cure for uncertainty is not only expensive but also may even add to the uncertainty by generating unexpected abnormal or false positive values. The uses of blood tests may thus even increase uncertainty and stimulate further unnecessary diagnostic investigations (19, 20). It is important, therefore, that once the decision to obtain blood tests has been made, appropriate test ordering is adhered to. Physicians' use of blood tests, however, is not always appropriate (17, 18, 21-24). Dutch investigators report a lack of general practitioners' knowledge concerning the indications for blood tests leading to inappropriate and inadequate use of diagnostic tests (25). The need to improve the ordering of blood tests, however, is not limited to The Netherlands; investigators in other countries also argue that improving the quality of blood test ordering deserves attention.(26-28)

In The Netherlands, three methods have proven to be effective in changing test-ordering behavior of the general practitioner: (a) providing personal feedback, (b) reducing the number of options available on the order form, and (c) introducing indication-oriented order forms based on guidelines.

Pop and Winkens investigated the influence of personal feedback on test ordering behavior of Dutch general practitioners. Participating general practitioners ordered blood tests using a paper form on which they also recorded the indication for the tests. Twice a year, an internist provided each general practitioner feedback that compared his or her behavior with the test-ordering behavior of the other participating general practitioners. The internist would subsequently discus the indications, and provide suggestions for more rational test ordering. In a three-year period, the total amount of blood tests ordered by general practitioners decreased by a third. (29-33). An important disadvantage of this approach, however, is that it is time consuming and expensive.

Zaat pioneered reducing the number of tests available on the order form in The Netherlands (25). Zaat modified the order form by simply removing rarely indicated tests. At the bottom of the order form, space was available where the general practitioner could write down other tests. The introduction of a restricted form of 15 blood tests decreased the number of blood tests ordered by 18%. A restricted form is a simple and easy method for reducing the number of tests ordered by general practitioners (14, 25).

The third method of changing test-ordering behavior of Dutch general practitioners involves the introduction of indication-oriented order forms based on guidelines. On these forms, tests are grouped by indication. These forms proved effective in reducing the number of blood tests ordered by general practitioners (34-36)

In The Netherlands, the majority of general practitioners have replaced their traditional paper-based medical record with electronic patient records (37). These general practitioners use the computer during patient encounters to record the medical data. Many investigators argue that the use of electronic patient records provides new opportunities for decision support (38-40); they argue that the integration of decision support facilities with the electronic patient record provides a natural way to integrate that support in day-to-day practice. The use of a decision support system for test ordering has to become part of the normal workflow, i.e. it should not require prohibitive additional time when compared to ticking the boxes on a paper form. Taking advantage of the use of electronic patient records by Dutch general practitioners, we want to replace the traditional test ordering paper forms by a decision support system.

3.3 Designing the System

The objective of the decision support system is to change test-ordering behavior. Building a system to change test-ordering behavior, however, requires us to select a method we will follow when providing support. We decided to use two methods: the restricted order form method and the

indication-oriented order form. To study these two methods for changing test-ordering behavior, we developed two versions of the decision support system BloodLink. The first version, *BloodLink-Restricted*, is based on the notion of restricting the number of choices presented to the general practitioners. The second version, *BloodLink-Guideline*, is based on the guidelines provided by the Dutch College of General Practitioners. Implementation of both strategies allows us to study differences between the two methods. We will first describe these two versions of BloodLink.

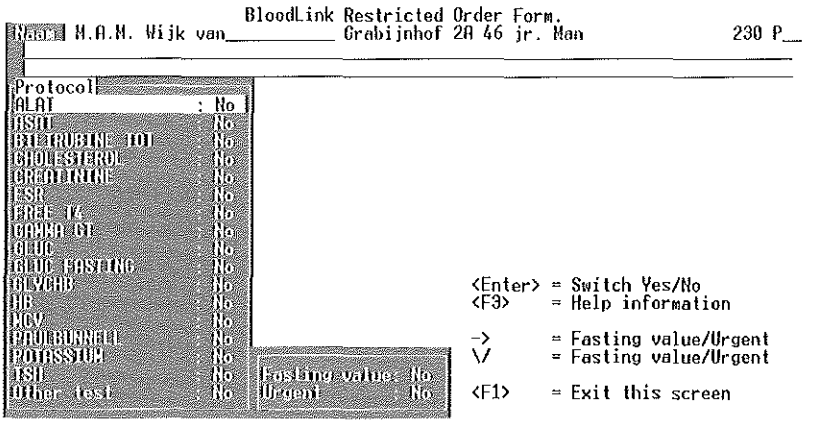
3.3.1 BloodLink-Restricted

In The Netherlands, one effective method to change test-ordering behavior of general practitioners is based on reducing the number of tests that are shown on the order form. Zaat developed a restricted paper order form that replaced the existing form with a new form that listed only 15 tests (13). The original paper order form listed a total of 178 different tests. Many of these tests are rarely indicated in general practice. On the restricted order form, the rarely indicated tests were left out. To order a rarely indicated test, the general practitioner could write the name of the required test in a section at the bottom of the form. Having designed a simplification of the order form, Zaat did a one-year-intervention study in an experimental group, using the restricted order form. The control group retained the familiar order form that listed 178 tests. The average number of tests per month decreased by 18% in the experimental group. Reintroducing the previous order form, however, showed a return to the original levels before intervention.

BloodLink-Restricted is based on providing the general practitioner with an electronic version of a restricted order form. The general practitioner, using the electronic patient record, can activate BloodLink to order blood tests. BloodLink offers the general practitioner an alphabetic list of 15 tests. These 15 tests were judged by Zaat to be the most relevant in primary care. Figure 1 shows the screen of BloodLink-Restricted with these 15 tests. The general practitioner chooses from this list the relevant tests. The general practitioner may add other not listed tests by simply typing the initial letters of the desired test. BloodLink will subsequently show a list of all tests beginning with those letters from which the general practitioner may choose the desired test(s). Options for specific instructions to the laboratory (for example, urgent, or

fasting value) are available (See Figure 1). BloodLink-Restricted subsequently prints a patient-specific blood order form that includes the necessary patient data (such as name, age, address, etc.), the tests ordered and the specific instructions for the laboratory. Finally, the system updates the patient record to show which tests have been ordered.

Figure 1: The restricted form



This figure shows the list of 15 alphabetical ordered tests. The general practitioner chooses from this list the relevant tests. The general practitioner may add other not listed tests by typing the initial letters of the desired test

3.3.2 BloodLink-Guideline

Several Dutch investigators have used guidelines issued by the Dutch College of General Practitioners to construct indication-oriented order forms (34-36). These guidelines assist general practitioners in dealing with specific clinical conditions in a primary care setting. On these forms, tests are grouped by indication. Studies with these order forms have shown impact on test-ordering behavior (35). A major limitation of these studies is that they involve only a small subset of the available practice guidelines.

BloodLink-Guideline is based on the recommendations for test ordering as provided by the Dutch College of General Practitioners. Until January 1st 1996, the Dutch College of General Practitioners had published in total 54 guidelines. The College regularly updates the guidelines. We analyzed the most recent version of each guideline that was available on January 1st 1996 (41). For each of the guidelines, we analyzed each sentence to determine whether that sentence contained a reference to a blood test. If the sentence contained a reference to blood tests, we determined the clinical situation in which the test should be performed (the indication), and determined the tests that should be performed in that situation (the recommended tests).

Of the 54 guidelines, 23 guidelines mentioned blood tests and allowed us to identify the indication for those tests (41). We distinguished five different categories of indications. The *first* category of indications describes clinical situations in which the general practitioner considers a diagnosis, the working diagnosis. This working diagnosis is the most probable diagnosis based on the patient's medical history and/or physical examination. The general practitioner subsequently uses the blood tests to support or refute that diagnosis.

The *second* category of indications describes clinical situations in which the general practitioner has established a diagnosis, and uses the laboratory to investigate underlying pathology that could cause the disease. The crucial difference with the category working diagnosis is that in case of underlying pathology the guideline requires that the general practitioners has already established the presence of a specific diagnosis. Given the presence of this specific diagnosis, the guideline specifies the evaluation of possible causes of that diagnosis.

The *third* category of indications involves monitoring the course of a disease. The general practitioner has established the diagnosis, and is monitoring the progression of the disease.

The *fourth* category of indications describes situations in which blood tests are used to select appropriate treatment. In these situations, the general practitioner has established the diagnosis, and the blood tests are used to identify factors that have a direct bearing on the choice of subsequent

treatment. Based on the results of these blood tests, the guideline specifies the treatment of choice.

The *fifth* category of indications describes situations in which blood tests are used to monitor the side effects of drugs. The guidelines state that for certain drugs, the general practitioner should monitor the patient for potential side effects of the drugs. In some instances, this requires periodic blood testing. The results of the blood tests might lead to modification of prescribe dosages or termination of the treatment with that drug.

The analysis of the guidelines shows that the guidelines contain specific and detailed recommendations for ordering blood tests. Given the fact that previous studies have reported a lack of general practitioners' knowledge concerning indications for tests, the guidelines could provide needed support. (25, 42). These recommendations, however, are scattered throughout many different guidelines (a total of 23 out of the 54 practice guidelines); the currently available paper-based guidelines require the general practitioner to spend time and effort to locate and interpret the recommendations for blood tests.

From the perspective of a system builder, our objective was to identify the specific recommendations for test ordering. From this perspective we conclude that the guidelines contain concrete and specific recommendations, and that only few inconsistencies were found. Identifying the indication for requesting blood tests is a possible method for analyzing the guidelines with respect to recommendations for test ordering. The indication for blood tests is the specific question of the general practitioner to which obtaining the tests will provide a (partial) answer. We conclude that the recommendations for blood tests in the guidelines of the Dutch College of General Practitioners are focused on describing what tests are necessary in the context of a given indication.

Based on these notions, we developed the system BloodLink-Guideline. The general practitioners, using the electronic patient record, can activate BloodLink to order blood tests. BloodLink-Guideline first provides an overview of the available guidelines (See Figure 2). In The Netherlands, the

names of these guidelines are familiar to general practitioners. The guidelines are published in the journals, taught in medical school, and included in mandatory continuing medical education. We have, therefore, decided to adhere to the names of these guidelines as much as possible. The general practitioner selects the appropriate guideline, for example liver disease. A guideline may describe several different indications for requesting blood tests; for example, the guideline "Blood tests and liver disease" mentions ten different indications. Once the general practitioner has selected a guideline, BloodLink-Guideline queries the general practitioner about the reasons for requesting the test(s) until an indication is identified. Depending on the number of indications mentioned in the guideline, the general practitioner has to answer up to three questions. When the general practitioner has, for example, selected liver disorders (See Figure 3), the next questions deal with the disease involved (e.g., hepatitis B), and the indication (e.g., monitoring the course of hepatitis B). Optional help texts are available at each selection that explain the choices, and provide the relevant sections of the guidelines. After the indication has been identified, the system proposes the relevant tests. Figure 4 shows the recommended tests when the indication is monitoring the course of hepatitis B. The general practitioner makes the decision of protocol adherence; the practitioner may add test(s) to or remove test(s) from the proposed list. Options for specific instructions to the laboratory (e.g., urgent, or fasting value) are available (See Figure 4). BloodLink-Guideline subsequently prints a patient-specific test order form that includes the necessary patient data (such as name, age, address, etc.), the tests requested, and the additional instructions for the laboratory. Finally, BloodLink-Guideline updates the patient record to show which test(s) have been requested.

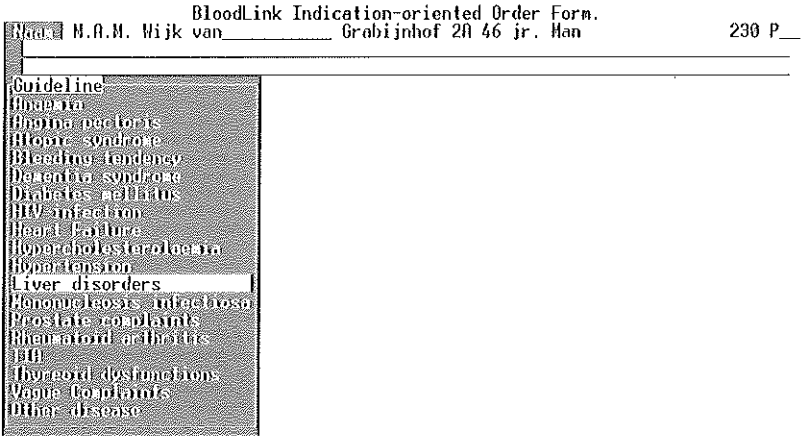


Figure 2: Selecting the guideline.

This figure shows the main window containing the guidelines for which BloodLink-Guideline has implemented the recommendations for ordering of blood tests. The general practitioner selects the guideline liver disorders.

Although new guidelines are published at regular intervals, the currently available guidelines of the Dutch general practitioners cover only a limited set of indications for blood tests (41). In the absence of national guidelines, local or regional guidelines may exist. The version of BloodLink-Guideline used in the region of Delft, The Netherlands, includes in addition to all national guidelines a total of three regional guidelines: anemia, aids, and bleeding disorders. Even with these additional guidelines, BloodLink-Guideline does not cover all possible indications for blood tests in primary care. To deal with those situations where the general practitioner's indication is not available in BloodLink, the general practitioner can select the heading "other indication". If the general practitioner selects the heading "other indication", BloodLink-Guideline is, of course, not able to provide recommendations for test ordering; the general practitioner has to select himself the required test(s) by typing the initial letters of the test(s).

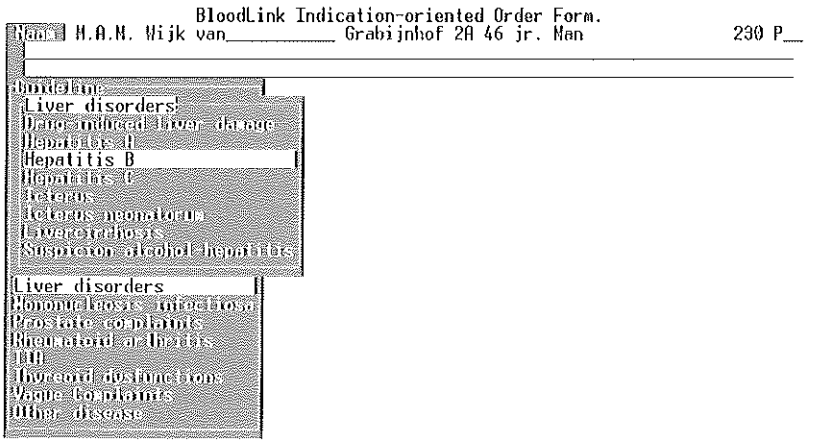


Figure 3: Selecting the indication.

BloodLink-Guideline queries the general practitioner about the reasons for requesting the test(s) until an indication is identified. The general practitioner has already selected the guideline liver disorders. The next selection deals with the disease involved. The general practitioner selects hepatitis B.

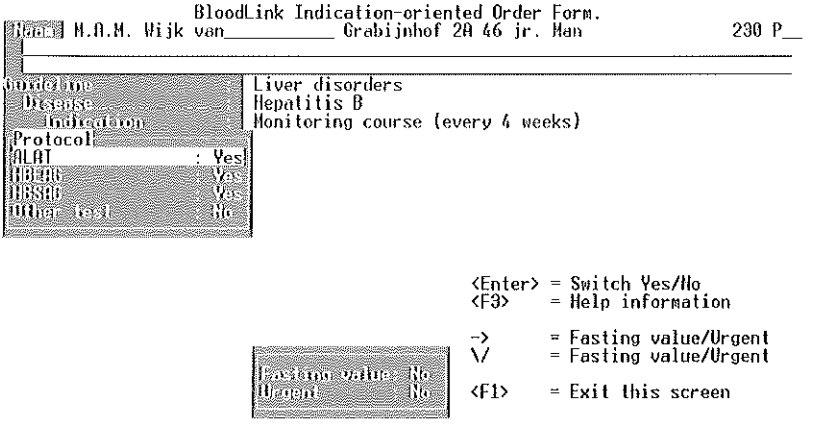


Figure 4: The recommendations of BloodLink-Guideline for monitoring the course of hepatitis B.

This figure shows the recommended tests when the indication is monitoring the course of hepatitis B. The physician can add additional tests and information for the laboratory (fasting value or urgent test).

3.4 Discussion

Increasingly literature shows that providing decision support is able to change health care delivery (43-48). As the number of studies that show an impact increases, the choices faced by a system designer also increase. To provide decision support, a number of different methods may be available (46). Studies that compare these different methods in, for example, a randomized trial are often not available. As a result, the developer of a decision support system is forced to compare the results of studies that are conducted in different settings, use different methods, and involve different populations.

Our objective was to build for one medical domain two systems using two different methods. In our case, the domain is blood test ordering. The resulting systems will be the subject of trials in which we will compare the impact of these systems. The methods we follow is that of displaying a reduced list of tests, BloodLink-Restricted, and displaying recommendations for test ordering from the guidelines of the Dutch College of General Practitioners, BloodLink-Guideline. The only difference between the two versions of BloodLink is the method used to present the initial set of tests to the general practitioner. In all other respects, the two versions of the system are identical: the same integration with the computer-based medical record, the same layout of the screens, the same abbreviations of the tests, the same mechanism by which the general practitioner can add or remove tests, the same form printed, and the same notes left in the medical record.

Studies with a paper order form listing a reduced number of tests have shown to be effective in changing test-ordering behavior (13, 49). BloodLink-Restricted is a straightforward electronic equivalent of such a paper order form. BloodLink-Guideline, however, is more than the implementation of the existing indication-oriented forms based on guidelines. The nature of a paper form does not allow the expression of the detail and complexity of the currently available guidelines (50). Studies conducted with paper forms that are based on guidelines, therefore, have been limited to only a few guidelines. The paper forms based on a limited set of guidelines do not solve the fundamental problem of getting guidelines into practice. Many investigators have lamented the fact that the availability of guidelines is no guarantee for use by physicians (50-52). In the ideal situation, the decision support system

provides the general practitioner with guideline-based recommendations for test ordering during patient consultation. The development of an electronic indication-oriented test order form, however, requires that guidelines of sufficient clarity be available.

The guidelines of the Dutch College of General Practitioners contain concrete and specific recommendations for test ordering (41). The indication for blood tests is the specific question of the general practitioner to which obtaining the test will provide an answer. For researchers in Medical Informatics, this notion of the indication as the general practitioner's question has significant consequences for designing a decision support system. Given the concept of the indication, the designer faces a choice.

The first alternative is, given the patient symptoms, that the system identifies the indication for blood tests. If the objective is to support the identification of the indication, the decision support system will require detailed information about the patient's condition. This approach requires the physician to enter patient data. Based on the available data, the system could generate indications, select among these, and prepare a recommendation for test ordering. Some of the required patient data may be already available in the electronic patient record. By integrating the system with the medical record, the system could automatically retrieve that data. As a result, the need to have the physician enter data in the system could be reduced. If the identification of the indication is based on the data in the electronic patient record, the accuracy of that data is of critical importance. The levels of accuracy in electronic patient records, however, have been reported as varying (53-55). In addition, the identification of indications requires a formal decision model (for example, a Baysian model) that translates the patient's symptoms to indications (56).

The second alternative is, given the indication, that the system selects the appropriate tests. If the objective of the system is to select the appropriate test given the indication, the decision support system will start asking the general practitioner questions about his or her indication; the translation of the patient's condition to a specific indication is left to the general practitioner. In this approach, the system does not require information about the patient's condition, but information from general practitioners about the indication

underlying the request for tests. In this approach, the system queries the general practitioner instead of interpreting the patient data.

The system builder thus has to determine whether the decision support is based on the patient's symptoms or on the general practitioner's indications. For the general practitioner, these two methods will result in two different systems. If the objective of the system is to select the appropriate test given the indication, the general practitioner has to answer questions about his or her indication and translate the patient's condition to a specific indication. If the objective of the system is to select the test given the symptoms of the patient, the general practitioner has to answer questions about the patient's symptoms or complaints; the system will, subsequently, determine the indication.

We decided to build a system that requests from the general practitioner the indication, BloodLink-Guideline. As a result, the system is driven by questions related to the objectives of the general practitioner and does not ask detailed questions about the symptoms or complaints of the patient. The downside of this approach is that the system does not support the general practitioner in establishing the appropriate indication based on the complaints of the patient. This decision is not only based on the fact that the guidelines provide recommendations on the level of indication. We also believe that especially general practitioners are able to, decision support systems can only deal with a very limited segment translate the often-complex presentation of patients' complaints to well-defined indications. Computers are only able to deal with those parts of the patient-physician encounter that can be translated to objective facts and numbers; as a result of reality. Other investigators have lamented the fact that decision support systems tend to ignore the intellect of the physician (57), and leave the practitioner with a sense of losing control (58). We believe that in the area of the initial interpretation of the symptoms of the patient the role of a decision support system should be very limited.

Although literature shows that different methods are able to change physicians' test-ordering behavior, little is known about which method is most effective. BloodLink represents an effort to change test-ordering behavior of general practitioners using two different methods. The objective is to provide a research environment that allows comparison of these different methods. Further research will have to show the impact of the different versions of

BloodLink on the test-ordering behavior of the general practitioner. At present, 60 general practitioners in the area of Delft, The Netherlands, are involved in a randomized trial in which the impact of both BloodLink-versions is compared. Initial results indicate that the system is used in the majority of cases (over 70% of the order forms the laboratory receives of these general practitioners are generated using the decision support system). Additional studies will have to assess the changes caused by the system in the use of the laboratory.

3.5 References

1. Kluijt I, Zaat JOM, Van der Velden J, van Eijk JTM, Schellevis FG. Voor een prikje: Huisarts en bloedonderzoek. Huisarts en Wetenschap 1991;34:67-71 *(The general practitioner and bloodtests. In Dutch, English abstract.).*
2. Summerton N. Positive and negative factors in defensive medicine: a questionnaire study of general practitioners. British Medical Journal 1995;310:27-9.
3. Kaplan SH, Greenfield S, Gandek B, Rogers WH, Ware JEJ. Characteristics of physicians with participatory decisions-making styles. Annals of Internal Medicine 1996;124:497-504.
4. Hewson MG, Kindy PJ, Van Kirk J, Gennis VA, Day RP. Strategies for managing uncertainty and complexity. Journal of General Internal Medicine 1996;11:481-5.
5. McKinlay JB, Potter DA, Feldman HA. Non-medical influences on medical decision-making. Social Sciences and Medicine 1996;42:769-76.
6. Hamm RM, Smith SL. The accuracy of patients' judgements of disease probability and test sensitivity and specificity. Journal of Family Practice 1998;47:44-52.
7. Veldhuis M. Defensive behavior of Dutch family physicians. Widening the concept. Family Medicine 1994;26:27-9.
8. Van Boven K, Dijksterhuis P, Lamberts H. Defensive testing in Dutch family practice. Is the grass greener on the other side of the ocean? Journal of Family Practice 1997;44:468-72.
9. Epstein AM, Begg CB, McNeil BJ. The effect of physicians' training and personality on test ordering for ambulatory patients. American Journal of Public Health 1984;74:1271-1273.
10. Rosser WW. Approach to diagnosis by primary care clinicians and specialists: is there a difference? Journal of Family Practice 1996;42:139-144.
11. Sox HC. Decision-making: a comparison of referral practice and primary care. Journal of Family Practice 1996;42:155-160.
12. Kristiansen IS, Hjortdahl P. The general practitioner and laboratory utilization: why does it vary? Family Practice 1992;9:22-27.

13. Zaat JO, Van Eijk JT, Bonte HA. Laboratory test form design influences test ordering by general practitioners in The Netherlands. Medical Care 1992;30:189-198.
14. Zaat JOM. General practitioners' uncertainty, risk preference, and use of laboratory tests. Medical Care 1992;30(9):846-854.
15. Grol R, Whitfield M, De Maeseneer J, Mokkink H. Attitudes to risk taking in medical decision making among British, Dutch and Belgian general practitioners. British Journal of General Practice 1990;40:134-136.
16. Holtgrave DR, Lawler F, Spann SJ. Physicians' risk attitudes, laboratory usage, and referral decisions: the case of an academic family practice center. Medical Decision Making 1991;11:125-130.
17. Ornstein SM, Markert GP, Johnson AH, Rust PF, Afrin LB. The effect of physician personality on laboratory test ordering for hypertensive patients. Medical Care 1988;26(6):536-543.
18. Kassirer JP. Our stubborn quest for diagnostic certainty. New England Journal of Medicine 1989;320(22):1489-1491.
19. Boohaker EA, Ward RE, Uman JE, McCarthy BD. Patient notification and follow-up of abnormal test results. A physician survey. Archives of Internal Medicine 1996;12:327-331.
20. DeKay ML, Asch DA. Is the defensive use of diagnostic tests good for patients, or bad? Medical Decision Making 1998;18:19-28.
21. Kassirer JP. Diagnostic reasoning. Annals of Internal Medicine 1989;110:893-900.
22. Axt-Adam P, Van der Wouden JC, Van der Does E. Influencing behavior of physicians ordering laboratory tests: A literature study. Medical Care 1993;31:784-794.
23. Eisenberg JM, Nicklin D. Use of diagnostic services by physicians in community practice. Medical Care 1981;19(3):297-309.
24. Wong ET, Lincoln TL. Ready! Fire! ...Aim. Journal of the American Medical Association 1983;250(18):2510-2513.
25. Zaat JOM. De macht der gewoonten: Over de huisarts en zijn laboratorium onderzoek [Thesis]. Amsterdam: Free University Amsterdam; 1991 *(On the General Practitioner and his laboratory-test ordering. In Dutch, English Summary).*
26. Van Walraven C, Naylor CD. Do we know what inappropriate laboratory utilization is? A systematic review of laboratory clinical audits. Journal of the American Medical Association 1998;280:550-558.
27. Van Walraven C, Goel V, Chan B. Effect of population-based interventions on laboratory utilization: a time-series analysis. Journal of the American Medical Association 1998;280:2028-33.

28. Solomon DH, Hashimoto H, Daltroy L, Liang MH. Techniques to improve physicians' use of diagnostic tests. Journal of the American Medical Association 1998;280:2020-2027.
29. Winkens RAG, Pop P, Grol RPTM. Effect of feedback on test-ordering behavior of general ractitioners. British Medical Journal 1992;304:1093-1097.
30. Pop P, Winkens RAG. A diagnostic centre for general practitioners: results of individual feedback on diagnostic actions. Journal of the Royal College of General Practitioners 1989;39:507-8.
31. Winkens RAG, Pop P, Grol RP, Bugter-Maessen AM, Kester AD, Beusmans GH, et al. Effects of routine individual feedback over nine years on general practitioners' requests for tests. British Medical Journal 1996;24:490.
32. Winkens RA, Bugter-Maessen AM, Grol RP, Kester AD, Beusmans GH, Knottnerus JA. Randomised controlled trial of routine individual feedback to improve rationality and reduce numbers of test requests. The Lancet 1995;25:498-502.
33. Bugter-Maessen AM, Winkens RA, Grol RP, Knottnerus JA, Kester AD, Beusmans GH, et al. Factors predicting differences among general practitioners in test-ordering behaviour and in the response to feedback on test requests. Family Practice 1996;13:254-8.
34. Smithuis LOMJ, Van Geldrop WJ, Lucassen PLBJ. Beperking van het laboratoriumonderzoek door een probleemgeorienteerd aanvraagformulier. Een partiële implementatie van NHG-standaarden. Huisarts Wet 1994;37:464-66 *(Reducing test ordering by introducing a problem-oriented order form. Partial implementation of the guidelines of the Dutch College of General Practitioners. In Dutch, English abstract).*
35. Van Gend JMWA, Van Pelt J, Cleef THM, Mangnus TM, Muris JWM. Kwaliteitsverbeteringsproject "laboratoriumdiagnostiek door huisartsen" leidt tot aanzienlijke reductie van het aantal laboratoriumanalysen. Ned Tijdschr Geneeskd 1996;140:495-500 *(The quality improvement project "laboratory test ordering by general practitioners", reduces the number of tests ordered. In Dutch, English abstract).*
36. Van Geldrop WJ, Lucassen PLBJ, Smithuis LOMJ. Een probleemgeoriënteerd aanvraagformulier voor laboratoriumonderzoek. Effecten op het aanvraaggedrag van huisartsen. Huisarts Wet 1992;35:192-196 (*A problem-oriented test order form. Impact on test ordering behavior of general practitioners).*

37. Van der Lei J, Duisterhout JS, Westerhof HP, Van der Does E, Cromme PVM, Boon WM, et al. The introduction of computer-based patient records in the Netherlands. Annals of Internal Medicine 1993;119:1036-1041.
38. Tierney WM, Overhage JM, Takesue BY, Harris LE, Murray MD, Vargo DL, et al. Computerizing guidelines to improve care and patient outcomes: the example of heart failure. Journal of the American Medical Informatics Association 1995;2:316-322.
39. Elson RB, Connelly DP. Computerized patient records in primary care. Their role in mediating guideline-driven behavior change. Archives of Family Medicine 1995;4:698-705.
40. Henry SB, Douglas K, Galzagorry G, Lahey A, Holzemer WL. A template-based approach to support utilization of clinical practice guidelines within a electronic record. Journal of the American Medical Informatics Association 1998;5:237-244.
41. Van Wijk MA, Bohnen AM, Van der Lei J. Analysis of the practice guidelines of the Dutch College of General Practitioners with respect to the use of blood tests. Journal of the American Medical Informatics Association 1999;6:322-331.
42. Schriger DL, Baraff LJ, Rogers WH, Cretin S. Implementation of clinical guidelines using a computer charting system. Effect on the initial care of health workers exposed to body fluids. Journal of the American Medical Association 1997;278:1585-90.
43. Margolis A, Bray BE, Gilbert EM, Warner HR. Computerized practice guidelines for heart failure management: the HeartMan system. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:228-32.
44. Hollingworth GR, Bernstein RM, Viner GS, Remington JS, Wood WE. Prompting for cost-effective test ordering: a randomized controlled trial. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:635-9.
45. Zielstorff RD. Online practice guidelines: issues, obstacles, and future prospects. Journal of he American Medical Informatics Association 1998;5:227-36.
46. Johnston ME, Langton KB, Haynes RB, Mathieu A. Effects of computer-based clinical decision support systems on clinicians' performance and patient outcome. Annals of Internal Medicine 1994;11:497-499.
47. Ohno-Machado L, Gennari JH, Murphy SN, Jain NL, Tu SW, Oliver DE, et al. The guideline interchange format: a model for representing

guidelines. Journal of the American Medical Informatics Association 1998;5:357-72.
48. Jenders RA, Hripcsak G, Sideli RV, DuMouchel W, Zhang H, Cimino JJ, et al. Medical decision support: experience with implementing the Arden Syntax at the Columbia-Presbyterian Medical Center. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:169-173.
49. Durand-Zaleski I, Rymer JC, Roudot-Thoraval F. Reducing unnecessary laboratory use with new request form: example of tumour markers. The Lancet 1993;342:150-3.
50. McColl A, Smith H, White P, Field J. General practitioners' perceptions of the route to evidence based medicine: a questionnaire survey. British Medical Journal 1998;316:361-365.
51. Lomas J. Words without action? The production, dissemination and impact of consensus recommendations. Annual Review of Public Health 1991;12:41-65.
52. Feder G, Eccles M, Grol R, Griffiths C, Grimshaw J. Using clinical guidelines. British Medical Journal 1999;318:728-30.
53. Hogan WR, Wagner MM. Accuracy of data in computer-based patient records. Journal of the American Medical Informatics Association 1997;4:342-55.
54. Litzelman DK, Tierney WM. Physicians' reasons for failing to comply with computerized preventive care guidelines. Journal of General Internal Medicine 1996;11:497-9.
55. Elson RB, Connelly DP. Computerized decision support systems in primary care. Primary Care 1995;22:365-84.
56. Miller PL, Frawley SJ. Trade-offs in producing patient-specific recommendations from a computer-based clinical guideline: a case-study. Journal of the American Medical Informatics Association 1995;2:238-242.
57. Miller RA, Masarie FE. The demise of the Greek oracle model for medical diagnosis systems. Methods of Information in Medicine 1990;29:1-2.
58. Taylor TR. The computer and clinical decision-support systems in primary care. Journal of Family Practice 1990;30((2)):137-140.

Chapter 4

Decision Support Can Change Physicians' Ordering of Blood Tests: a Randomized Clinical Trial

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4.1 Abstract

Background: Different methods for changing blood test ordering behavior in primary care have proven effective. Randomized trials comparing these methods have never been conducted.
Objective: To compare the effect of two versions of BloodLink, a computer-based clinical decision support system, on blood test ordering behavior of Dutch general practitioners.
Design: Randomized clinical trial.
Setting: 44 Practices of Dutch general practitioners in the region Delft.
Participants: 44 Practices (60 general practitioners) using computerized patient records.
Interventions: After stratification by single-handed practices and group practices, practices were randomized to BloodLink-Restricted, based on initially displaying a reduced list of tests, or to BloodLink-Guideline, based on the guidelines of the Dutch College of General Practitioners.
Measurements: The main outcome measure was the average number of blood tests ordered per order form per practice.
Results: General practitioners who had access to decision support based on guidelines requested on average 20 % fewer tests (5.5 tests versus 6.9 tests, respectively; Mann-Whitney test p=0.003, N=44) than general practitioners with access to decision support based on a form that initially displays a limited number of tests.
Conclusion: We conclude that decision support based on guidelines is more effective in changing blood test ordering behavior than decision support based on initially displaying a limited number of tests. Decision support systems can be effective in introducing guidelines in primary care.

4.2 Introduction

The majority of general practitioners in The Netherlands have replaced their traditional paper-based patient records with computer-based patient records, the physicians entering patient data themselves in the computer during patient encounters (1). The use of electronic patient records creates new opportunities for the implementation of decision support systems; integration of decision support facilities with electronic patient records provides a natural way to support clinical practice (2-7).

To provide decision support, a number of different methods may be available. In recent years, publications documented a range of computerized decision support systems and demonstrated their impact on physicians' behavior (8-17). Other investigators, however, report that computerized decision support failed to have an impact on patient care (18). As a result, investigators are forced to compare the results of studies that are conducted in different settings, use different methods, and involve different populations (19). Studies that compare different methods to provide computerized decision support in randomized trials are not available.

In The Netherlands, three to four percent of patient encounters with general practitioners in primary care results in ordering blood tests (20). Ordering of blood tests by physicians is not always appropriate (21-29). General practitioners become acquainted with test ordering when being trained in hospitals before settling down in primary care (30). Hospital morbidity, however, is different from morbidity patterns in primary care (31-33). Especially in a primary care setting with low disease prevalence, researchers argue that excessive test ordering causes abnormal or false positive values, in turn leading to additional, unnecessary diagnostic examinations (34, 35).

Our objective is to compare, in the domain of blood test ordering in primary care, two versions of the same decision support system; each version is based on a different method. Both 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 et al. developed a restricted order form that replaced the then existing form with a new paper form (36-38). The original form had a total of 178 different tests. The restricted order form had only 15 tests; to order other tests, the general practitioner could write the name of the required test in a section at the bottom of the form. In an intervention study, the average number of tests per month decreased by 18 percent (36-38). The second method involves the introduction of indication-oriented order forms, based on clinical practice guidelines (39-41). On the indication-oriented order forms, tests are grouped by indication. These forms proved to be effective in reducing the number of blood tests ordered by general practitioners (39-41).

4.3 Methods

4.3.1 Intervention

To study two methods for changing test-ordering behavior, we developed two versions of the decision support system BloodLink. Both versions of BloodLink were integrated with the computerized patient record. The general practitioner can activate BloodLink to order blood tests while using the electronic patient record as an alternative for using paper order forms. As the 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, he or she can type the first few letters of the name of the required test, and the system will present all possible matches (including possible typing errors of the general practitioner) for selection. During the intervention the number of tests the general practitioners had at their disposal was exactly the same as before the intervention. Options for specific instructions to the laboratory (e.g., "urgent processing", or "fasting values") are available. BloodLink subsequently prints a patient-specific test order form and necessary instructions for the laboratory. Finally, the system 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 notion of a restricted order form. BloodLink-Restricted offers the general practitioner an initial set of 15 tests that previous research has identified as covering most of the clinical situations in primary care (37). BloodLink-Restricted can be viewed as a general electronic order form that presents only 15 tests [1] on the screen, together with a field "other tests" that allows the physician to order any other blood test (42).

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 covering most clinical situations in primary care. We analyzed the most recent version of each guideline, available in January 1996 and analyzed whether it contained a reference to a blood test (43). We determined the clinical situation in which the test should be performed (the indication), and the tests that should be performed in that situation (the recommended 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 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.

[1] The 15 tests were: ALAT: alanine aminotransferase; ASAT: aspartate aminotransferase; Bilirubine total, Cholesterol; Creatinine; ESR: erythrocyte sedimentation rate; Free T4; GGT: Gamma-glutamyltransferase; Glucose (and Fasting Glucose); HbA1C; Hb; MCV: mean corpuscular volume; Paul Bunnell; Potassium; TSH: Thyroid Stimulating Hormone.

The general practitioner makes the decision of protocol adherence. At any time, the physician can alter 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 (43). In the absence of national guidelines, local or regional guidelines may exist. The version of BloodLink-Guideline used during the clinical trial in the region of Delft, The Netherlands, includes, in addition to all national guidelines, three regional guidelines for anemia, AIDS, and bleeding tendency. 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.

4.3.2 Participants

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

4.3.3 Randomization

To avoid contamination, we randomized at the level of the practice (44, 45). The practices were first stratified by single-handed practices and group practices (that is two or more general practitioners in the same practice). Each practice was subsequently assigned by simple random allocation to BloodLink-Restricted or BloodLink-Guideline for the complete study period. Randomization was performed with a table of random numbers by a researcher not involved in the study and who was blind to the identity of the practices.

After randomization 22 practices involving 30 general practitioners were assigned to BloodLink-Restricted and 24 practices, involving 32 general practitioners, were assigned to BloodLink-Guideline.

4.3.4 Protocol

After installation, a short instruction was given to the participating general practitioners about the use of the software by one of us (MW). During a three-month 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. For test ordering, physicians had the choice between either the BloodLink software or the traditional paper form; 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 irrespective of whether the general practitioner used paper forms or BloodLink The electronic patient record monitored the use of BloodLink by the general practitioners. To include the requests for blood tests that were done on traditional paper forms, we also retrieved from the regional laboratory all received requests for blood tests.

4.3.5 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 subsequently identified the most frequently ordered tests by locating the tests that accounted for 80 percent of the total number of tests ordered. For these frequently ordered tests, we computed per practice the percentage of order forms that included the test.

4.3.6 Data analysis

We compared the distribution of practice and general practitioner characteristics at baseline using t-tests. The differences in the number of tests per order form were analyzed using the Mann Whitney test (unit of analysis the practice). In order to explore whether the size of the practice, the composition of the practice (gender and average patients' age, type of insurance), and the test-ordering behavior of the general practitioner during

the previous period (July 1st 1994 through June 30th 1995) affected the difference between the two intervention arms, we conducted a multivariate Poisson regression taking the number of tests during the intervention period as count variables and the practice size as offset. For the frequently ordered tests, we computed per practice the percentage of order forms that included that test and applied Student's t-test (equal variance not assumed; unit of analysis the practice).

4.4 Results

In 46 practices, the BloodLink software was installed. In the three-month period during which the general practitioners were allowed to use BloodLink in their practices to become acquainted with the system, two single-handed practices (one assigned to BloodLink-Restricted, and the other to BloodLink-Guideline) did not want to proceed; the first general practitioner stated that the response time of his computer had deteriorated, and the second one did not like the software. Forty-four practices with a total of 60 general practitioners started and ended the intervention study: 21 practices involving 29 general practitioners assigned to BloodLink-Restricted and 23 practices, involving 31 general practitioners, assigned to BloodLink-Guideline.

4.4.1 Baseline Comparability

In the practices assigned to BloodLink-Restricted, a total of 77,336 patients were enrolled on March 1st 1996. Of these 77,336 patients, 41,174 (53.2%) were ensured through a sick fund, 37,397 (48.4%) were female, and the average age on March 1st 1996 was 36.2 years old (median 33.7 years, 25 percentile 21.0 years, 75 percentile 50.6 years). In the practices assigned to BloodLink-Guideline, a total of 78,461 patients were enrolled on March 1st 1996; 41,198 (52.5%) were ensured through a sick fund, 38,743 (49.4%) were female, and the average age on March 1st 1996 was 37.1 years old (median 34.7 years, 25 percentile 21.5 years, 75 percentile 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.

Table 1: Baseline characteristics of practices.

	BloodLink-Restricted (n=21)				BloodLink-Guideline (n=23)				P-value *
	Mean	Median	25 percentile	75 percentile	Mean	Median	25 percentile	75 percentile	
Enrolled population	3683	3399	2930	4400	3411	3205	2917	3796	0.357
Average age of population in years	36.3	36.3	35.1	37.8	37.1	37.6	35.0	39.4	0.467
Percentage female	48.3	49.4	48.2	50.0	49.5	49.9	49.0	50.3	0.213
Percentage ensured through sick fund	53.2	53.5	50.9	56.4	52.9	53.7	50.7	58.9	0.851
Average number of test per order form in the period July 1st 1994 through June 30th 1995 **	7.7	7.8	5.8	9.3	7.2	7.3	6.1	8.1	0.423

* t-test on means

** two cases missing in each group

Table 2: Baseline characteristics of general practitioners.

	BloodLink-Restricted (n=21)				BloodLink-Guideline (n=23)				P-value *
	Mean	Median	25 percentile	75 percentile	Mean	Median	25 percentile	75 percentile	
Age at start of study	43.7	42.0	38.7	48.2	43.2	43.0	39.0	47.0	0.771
Years of experience at start of study	16.5	15.0	12.5	22.2	15.6	16.0	12.0	20.0	0.563
CME credits in 1996	44.3	42.0	33.7	56.5	43.1	42.0	31.0	50.0	0.765
CME credits in 1997	51.7	47.0	38.0	56.5	43.7	43.0	31.0	60.0	0.126

* t-test on means

4.4.2 Number of Tests per Order Form per Practice

For test ordering, the general practitioner had the choice to use either BloodLink or the traditional paper form. Of the 12,742 order forms the laboratory received during the intervention period from the BloodLink-Restricted group, the general practitioners used the decision support software 11,151 times (88 percent of all orders) to order blood tests; for the remaining 1,591 orders they used the traditional paper order forms. Of the 12,668 order forms from the BloodLink-Guideline group, 9,091 (72 percent of all orders) were generated using the decision-support system. We calculated as summary variable the average number of tests ordered per order form per practice.

Table 3: Number of tests per order form per practice.

	Mean	SD	Median	25 percentile	75 percentile
BloodLink Restricted (n=21)	6.9	1.6	6.6	5.7	7.9
BloodLink-Guideline (n=23)	5.5*	0.9	5.6	4.6	6.2

* p=0.003, compared to BloodLink-Restricted

As shown in Table 3, general practitioners who had access to BloodLink-Guideline ordered significantly fewer (20%) tests per order form than general practitioners who had access to BloodLink-Restricted (5.5±0.9 tests versus 6.9±1.6 tests, respectively; Mann-Whitney test p=0.003, unit of analysis the practice). A multivariate Poisson regression taking the number of tests per patient while adjusting for demographic characteristics of the practice (gender, average patients' age, insurance type) and previous test-ordering behavior of the general practitioner (July 1st 1994 through June 30th 1995) also showed a lower number of tests per enrolled patient in the BloodLink-Guideline group ($P < 0.0001$) compared to the BloodLink-Restricted group.

In total, the general practitioners ordered 157,360 tests during the study period. Although the general practitioners requested in total 351 different laboratory tests, the 20 most frequently ordered tests accounted for 80 percent of the total number of ordered tests. Table 4 shows these 20 most frequently ordered tests. Table 4 also shows the percentage of order forms per practice

that include that test. In the BloodLink-Restricted group, for example, 61.2 percent of the order forms included an erythrocytes sedimentation rate test, and in the BloodLink-Guideline group 44.1 percent did so ($p<0.001$, Student's t-test, unit of analysis the practice, equal variances not assumed).

Table 4: For the 20 most frequently ordered tests, the percentage of order forms per practice that included that test.

	Percentage of order forms (standard deviation)		
Test	BloodLink-Restricted Group	BloodLink-Guideline Group	t-test, p-value
ESR	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)	0.22
WBC 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
Erythrocytes	34.7 (21.5)	24.3 (11.6)	0.06
MCV	34.4 (21.5)	23.0 (12.0)	0.04
WBC differential analysis	31.3 (16.2)	23.3 (7.2)	0.05
Cholesterol	28.7 (12.1)	25.7 (9.0)	0.35
TSH	26.9 (14.3)	25.3 (5.3)	0.63
Gamma-GT	31.3 (15.4)	16.9 (9.2)	<0.001
ALAT	24.7 (13.6)	15.2 (6.8)	0.008
Potassium	17.7 (11.3)	8.8 (5.4)	0.003
ASAT	16.7 (10.8)	8.5 (6.5)	0.005
Triglycerides	11.4 (9.9)	9.9 (6.5)	0.56
HDL-Cholesterol	11.7 (11.1)	9.5 (6.8)	0.44
Sodium	6.9 (7.4)	6.2 (3.5)	0.70
Free T4	8.4 (6.2)	4.8 (3.7)	0.03
Alkaline Phosphates	5.4 (4.9)	7.0 (5.4)	0.34

ESR:,erythrocyte sedimentation rate; WBC, white blood cells; MCV, mean corpuscular volume; TSH, thyroid stimulating hormone; gamma-GT, gamma-glutamyltransferase; ALAT, alanine aminotransferase; ASAT, aspartate aminotransferase; HDL, high-density lipoproteins.

4.5 Discussion

Increasingly, the literature shows that providing decision support is able to change health care delivery (8-13, 15). Our objective was to build and evaluate, for one medical domain, a decision support systems using two different methods. In our case, the domain was blood test ordering. The method we followed was either displaying an initially reduced list of tests, BloodLink-Restricted, or displaying recommendations for test ordering based on the guidelines of the Dutch College of General Practitioners, BloodLink-Guideline. Our objective was to compare these two versions in a randomized trial.

Although the introduction of the BloodLink software was not accompanied by any training program (only a short instruction was given) and the familiar paper forms were still available during the intervention period, the majority of the orders were placed using BloodLink. A possible reason for the ease of the introduction is that Dutch general practitioners are used to using computers to maintain their patient records. BloodLink-Restricted, however, was used more frequently than BloodLink-Guideline (88 percent versus 71 percent). A possible explanation for the difference between the use of computer-generated order forms between the intervention groups is that, compared to BloodLink-Guideline, the interface of BloodLink-Restricted is more similar to the usual paper order form. In addition, BloodLink-Guideline does not cover al indications. General practitioners will soon learn that certain indications are not available and may decide to use the traditional paper form because filling the paper form is faster than selecting the individual tests using BloodLink-Guideline.

BloodLink-Guideline showed a reduction in tests per order when compared to BloodLink-Restricted (5.5 tests ordered per form versus 6.9 tests). For some frequently ordered tests, we observed a large difference between the BloodLink-Guideline and BloodLink-Restricted groups: a difference of 28 percent for erythrocyte sedimentation rate (61.2 percent versus 44.1 percent of the order forms), 32 percent for creatinine, 46 percent for gamma-glutamyltransferase, and 49 percent for aspartate aminotransferase. For other tests, however, there were no significant differences (e.g., glucose, cholesterol,

thyroid stimulating hormone, HDL-cholesterol, erythrocytes, sodium, and alkaline phosphates). We conclude that the overall reduction of ordered tests in the BloodLink-Guideline group is caused predominantly by a decrease in the ordering of some specific tests. BloodLink-Guideline does not reduce all test ordering in the same degree, but singles out a number of tests.

We believe that BloodLink-Guideline generally eliminated unnecessary tests rather than beneficial tests. First, for some tests we observe little or no difference between the groups. Thyroid stimulating hormone (TSH), for example, shows no significant difference between both groups. In ordering Free T4, however, there is a significant difference between the BloodLink-Restricted group and the BloodLink-guideline group. This could be the reflection of the fact that the BloodLink-Restricted users, order Free T4, while listed, simultaneously with TSH. However, according to the guideline for thyroid dysfunction issued by the Dutch College of General Practitioners, Free T4 should only be tested in case of abnormal TSH values. Another example of a frequently ordered test that shows little difference between both groups is glucose; glucose has a well-defined indication in confirming, excluding and monitoring diabetes mellitus. Second, the general practitioner using BloodLink-Guideline made the decision of protocol adherence. At any time, the physician could decide not to adhere to the system's recommendations for an individual patient by adding or removing tests from the proposed list. During the study period, the general practitioners using BloodLink-Guideline removed 1135 times one or more tests from the system's recommendations and added 4210 times one or more tests. We conclude that if the general practitioner would completely adhere to the recommendations for test ordering of the guidelines, a still greater reduction would be attained. Further research will have to clarify whether our belief that unnecessary tests are eliminated is correct.

The fact that in our study 20 tests accounted for 80 percent of the total number of tests ordered supports the notion that a limited number of tests satisfies the requirements for test ordering in most situations in primary care (36). BloodLink-Guideline, based on five categories of indications and involving 68 different indications (43), requires a total of 37 different tests. Although BloodLink-Guideline supports the use of 37 tests as compared to the 15 alphabetically ordered tests listed in BloodLink-Restricted, the use of

BloodLink-Guideline results in a much larger reduction in ordered 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, based on medical knowledge related to a specific indication. BloodLink-Guideline enables physicians to apply the medical knowledge of guidelines, whereas BloodLink-Restricted applies the notion of an initially limited set of tests that should fit most circumstances. Our study indicates that, in the domain of 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 merely reducing the form to a limited set of tests.

Many investigators have lamented the fact that the availability of guidelines is no guarantee for use by physicians (46-48). In the domain of blood test ordering, paper forms had been used to change physician behavior. The nature of a paper form, however, does not allow the expression of detail and complexity of currently available 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 as provided by the guidelines of the Dutch College of General Practitioners. This study showed that BloodLink-Guideline was used for the majority of test ordering. This study provides additional evidence that computerized decision support systems can be an effective method to introduce guidelines in daily practice. We were able to perform this study because the majority of general practitioners in The Netherlands have replaced their traditional paper-based patient records with computerized patient records. This study underscores the potential advantage of computerized patient records as a vehicle for changing physicians' behavior (49). In view of the little effort that was needed for the introduction of BloodLink in daily practice, the changes we found in test-ordering behavior could well be replicated elsewhere in primary care practices using computerized patient records. The results of this study may encourage the use of computerized patient records to enter patient data during patient encounters.

4.6 References

1. Van der Lei J, Duisterhout JS, Westerhof HP, Van der Does E, Cromme PVM, Boon WM, et al. The introduction of computer-based patient records in the Netherlands. Annals of Internal Medicine 1993;119:1036-1041.
2. Baily GG, Hammer MR, Hanley SP, Pattrick MG, De Kretser DM. Implementing clinical guidelines. Computers allow instant access. British Medical Journal 1993;307:679.
3. Tierney WM, Overhage JM, Takesue BY, Harris LE, Murray MD, Vargo DL, et al. Computerizing guidelines to improve care and patient outcomes: the example of heart failure. Journal of the American Medical Informatics Association 1995;2:316-322.
4. Elson RB, Connelly DP. Computerized patient records in primary care. Their role in mediating guideline-driven behavior change. Archives of Family Medicine 1995;4:698-705.
5. Connelly DP, Willard KE, Hallgren JH, Sielaff BH. Closing the clinical laboratory testing loop with information technology. American Journal of Clinical Pathology 1996;105:S40-7.
6. Henry SB, Douglas K, Galzagorry G, Lahey A, Holzemer WL. A template-based approach to support utilization of clinical practice guidelines within an electronic record. Journal of the American Medical Informatics Association 1998;5:237-244.
7. Chin H, Wallace P. Embedding guidelines into direct physician order entry: simple methods, powerful results. Proceedings AMIA Symp 1999 1999:221-5.
8. Johnston ME, Langton KB, Haynes RB, Mathieu A. Effects of computer-based clinical decision support systems on clinicians' performance and patient outcome. Annals of Internal Medicine 1994;11:497-499.
9. Margolis A, Bray BE, Gilbert EM, Warner HR. Computerized practice guidelines for heart failure management: the HeartMan system. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:228-32.
10. Hollingworth GR, Bernstein RM, Viner GS, Remington JS, Wood WE. Prompting for cost-effective test ordering: a randomized controlled trial. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:635-9.

11. Zielstorff RD. Online practice guidelines: issues, obstacles, and future prospects. Journal of the American Medical Informatics Association 1998; 5:227-36.
12. Ohno-Machado L, Gennari JH, Murphy SN, Jain NL, Tu SW, Oliver DE, et al. The guideline interchange format: a model for representing guidelines. Journal of the American Medical Informatics Association 1998;5:357-72.
13. Jenders RA, Hripcsak G, Sideli RV, DuMouchel W, Zhang H, Cimino JJ, et al. Medical decision support: experience with implementing the Arden Syntax at the Columbia-Presbyterian Medical Center. Proceedings of the Annual Symposium of Computer Applications in Medical Care 1995 1995:169-173.
14. Hunt DL, Haynes RB, Hanna SE, Smith K. Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. Journal of the American Medical Association 1998;15:1339-46.
15. Smith BJ, McNeely MDD. The influence of an expert system for test ordering and interpretation on laboratory investigations. Clinical Chemistry 1999;45:1168-1175.
16. Shiffman RN, Liaw Y, Brandt CA, Corb GJ. Computer-based guideline implementation systems: a systematic review of functionality and effectiveness. Journal of the American Medical Informatics Association 1999;6:104-14.
17. Cannon DS, Allen SN. A comparison of the effects of computer and manual reminders on compliance with a mental health clinical practice guideline. Journal of the American Medical Informatics Association 2000;7:196-203.
18. Montgomery AA, Fahey T, Peters TJ, Macintosh C, Sharp DJ. Evaluation of computer based clinical decision support system and risk chart for management of hypertension in primary care: randomised controlled trial. British Medical Journal 2000;320:686-90.
19. Cook DJ, Greengold NL, Ellrodt AG, Weingarten SR. The relation between systematic reviews and practice guidelines. Annals of Internal Medicine 1997;127:210-6.
20. Kluijt I, Zaat JOM, Van der Velden J, van Eijk JTM, Schellevis FG. Voor een prikje: Huisarts en bloedonderzoek. Huisarts en Wetenschap 1991;34:67-71 *(The general practitioner and bloodtests. In Dutch, English abstract.)*.
21. Ornstein SM, Markert GP, Johnson AH, Rust PF, Afrin LB. The effect of physician personality on laboratory test ordering for hypertensive patients. Medical Care 1988;26(6):536-543.

22. Kassirer JP. Our stubborn quest for diagnostic certainty. New England Journal of Medicine 1989;320(22):1489-1491.
23. Kassirer JP. Diagnostic reasoning. Annals of Internal Medicine 1989;110:893-900.
24. Axt-Adam P, Van der Wouden JC, Van der Does E. Influencing behavior of physicians ordering laboratory tests: A literature study. Medical Care 1993;31:784-794.
25. Eisenberg JM, Nicklin D. Use of diagnostic services by physicians in community practice. Medical Care 1981;19(3):297-309.
26. Wong ET, Lincoln TL. Ready! Fire! ...Aim. Journal of the American Medical Association 1983;250(18):2510-2513.
27. Van Walraven C, Naylor CD. Do we know what inappropriate laboratory utilization is? A systematic review of laboratory clinical audits. Journal of the American Medical Association 1998;280:550-558.
28. Van Walraven C, Goel V, Chan B. Effect of population-based interventions on laboratory utilization: a time-series analysis. Journal of the American Medical Association 1998;280:2028-33.
29. Solomon DH, Hashimoto H, Daltroy L, Liang MH. Techniques to improve physicians' use of diagnostic tests. Journal of the American Medical Association 1998;280:2020-2027.
30. Epstein AM, Begg CB, McNeil BJ. The effect of physicians' training and personality on test ordering for ambulatory patients. American Journal of Public Health 1984;74:1271-1273.
31. Rosser WW. Approach to diagnosis by primary care clinicians and specialists: is there a difference? Journal of Family Practice 1996;42:139-144.
32. Sox HC. Decision-making: a comparison of referral practice and primary care. Journal of Family Practice 1996;42:155-160.
33. Kristiansen IS, Hjortdahl P. The general practitioner and laboratory utilization: why does it vary? Family Practice 1992;9:22-27.
34. Boohaker EA, Ward RE, Uman JE, McCarthy BD. Patient notification and follow-up of abnormal test results. A physician survey. Archives of Internal Medicine 1996;12:327-331.
35. DeKay ML, Asch DA. Is the defensive use of diagnostic tests good for patients, or bad? Medical Decision Making 1998;18:19-28.
36. Zaat JO, Van Eijk JT, Bonte HA. Laboratory test form design influences test ordering by general practitioners in The Netherlands. Medical Care 1992;30:189-198.
37. Zaat JOM. De macht der gewoonten: Over de huisarts en zijn laboratorium onderzoek [Thesis]. Amsterdam: Free University

Amsterdam; 1991 *(On the General Practitioner and his laboratory test ordering. In Dutch, English Summary).*

38. Zaat JOM. General practitioners' uncertainty, risk preference, and use of laboratory tests. Medical Care 1992;30(9):846-854.
39. Smithuis LOMJ, Van Geldrop WJ, Lucassen PLBJ. Beperking van het laboratoriumonderzoek door een probleemgeoriënteerd aanvraagformulier. Een partiële implementatie van NHG-standaarden. Huisarts Wet 1994;37:464-66 *(Reducing test ordering by introducing a problem-oriented order form. Partial implementation of the guidelines of the Dutch College of General Practitioners. In Dutch, English abstract).*
40. Van Gend JMWA, Van Pelt J, Cleef THM, Mangnus TM, Muris JWM. Kwaliteitsverbeteringsproject "laboratoriumdiagnostiek door huisartsen" leidt tot aanzienlijke reductie van het aantal laboratoriumanalysen. Ned Tijdschr Geneeskd 1996;140:495-500 *(The quality improvement project "laboratory test ordering by general practitioners", reduces the number of tests ordered. In Dutch, English abstract).*
41. Van Geldrop WJ, Lucassen PLBJ, Smithuis LOMJ. Een probleemgeoriënteerd aanvraagformulier voor laboratoriumonderzoek. Effecten op het aanvraaggedrag van huisartsen. Huisarts Wet 1992;35:192-196 (*A problem oriented test-order form. Impact on test ordering behavior of general practitioners).*
42. Van Wijk M, Mosseveld M, Van der Lei J. Design of a decision support system for test ordering in general practice: choices and decisions to make. Methods of Information in Medicine 1999;38:355-61.
43. Van Wijk MA, Bohnen AM, Van der Lei J. Analysis of the practice guidelines of the Dutch College of General Practitioners with respect to the use of blood tests. Journal of the American Medical Informatics Association 1999;6:322-331.
44. Eccles M, Grimshaw J, Steen N, Parkin D, Purves I, McColl E, et al. The design and analysis of a randomized controlled trial to evaluate computerized decision support in primary care: the COGENT study. Family Practice 2000;17:180-6.
45. Kerry SM, Bland JM. Trials which randomize practices I: how should they be analysed? Family Practice 1998;15:80-3.
46. Lomas J, Anderson GM, Domnick-Pierre K, Vayda E, Enkin MW, Hannah WJ. Do practice guidelines guide practice? The effect of a consensus statement on the practice of physicians. New England Journal of Medicine 1989;321:1311-1315.

47. McColl A, Smith H, White P, Field J. General practitioners' perceptions of the route to evidence based medicine: a questionnaire survey. British Medical Journal 1998;316:361-365.
48. Grol R, Dalhuijsen J, Thomas S, Veld C, Rutten G, Mokkink H. Attributes of clinical guidelines that influence use of guidelines in general practice: observational study. British Medical Journal 1998;317:858-861.
49. Van Bemmel JH, Van Ginneken AM, Van der Lei J. A progress report on computer-based patient records in Europe. In: Detmer D, Steen EB, editors. The computer-based patient record. Washington DC: National Academy Press; 1997. p. 21-43.

Chapter 5

The Compliance of General Practitioners to a Guideline Based Decision Support System for Ordering Blood Tests

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5.1 Abstract

Background: To deal with the rapidly expanding body of medical knowledge, guidelines are increasingly viewed as a mechanism for distributing knowledge to physicians. We determined the compliance of Dutch general practitioners to the recommendations for test ordering as defined in the guidelines of the Dutch College of General Practitioners.

Methods: To implement the recommendations for test ordering, the authors have built the indication-oriented test-ordering module BloodLink-Guideline. BloodLink-Guideline was integrated with the electronic patient records of 31 general practitioners, practicing in 23 practices (16 single-handed). We determined compliance by comparing the recommendations for test ordering with the actually ordered test(s) per indication. The study was conducted from March 1996 through February 1997. To assess if non-compliance was related to pending revision of guidelines, we analyzed which guidelines had been revised after the intervention period and compared the three most frequently added tests in the non-compliant order forms with the recommendations of the updated guideline.

Main Outcome Measures: Compliance was expressed as the percentage of order forms per practice and per indication that follow the recommendations for test ordering of the guidelines of the Dutch College of General Practitioners.

Results: Twelve indications accounted for more than 80 percent of the indication-oriented order forms. The most frequently used indication for test ordering was "vague complaints" (30.1 % of all indications). Thirty-nine percent of the indication-oriented order forms were compliant. Removing tests is rare compared to adding tests. Many of the modifications that caused the order form to be non-compliant are supported by revisions of guidelines after the intervention period. For example, HDL-cholesterol, added in 79.2 percent of the non-compliant order forms, is included in the recommendations of the revised guideline *Hypercholesterolemia*. Likewise, HbA1C, added in 71.2 percent of the non-compliant order forms, is included in the recommendations of the revised guideline *Diabetes Mellitus*.

Conclusion: General practitioners rely on guideline-based test recommendations as a basic minimum for test ordering in daily practice but at the same time anticipate on pending revision of guidelines. Disregarding this aspect might lead to pointlessly focusing on barriers to physician guideline adherence.

Keywords: Family Practice, Compliance to Practice Guidelines (standards), Diagnostic Tests, Laboratories, and Test-ordering Behavior.

5.2 Introduction

The increased availability of diagnostic tests over the past decades has been accompanied by an increased number of blood tests, ordered by general practitioners. Dutch investigators report a lack of general practitioners' knowledge concerning the indications for blood tests leading to inappropriate and inadequate use of diagnostic tests (1, 2). Investigators in other countries also argue that improving the quality of blood test ordering deserves attention (3-6)

To deal with the rapidly expanding body of medical knowledge, guidelines are increasingly viewed as a mechanism for distributing knowledge to physicians (7, 8). Governmental agencies and professional organizations are developing clinical practice guidelines. In The Netherlands, the Dutch College of General Practitioners issues guidelines for the general practitioner. The procedure of creating a guideline consists of four stages (9). The first stage involves the selection of appropriate topics for new guidelines by an independent advisory board. The guidelines are intended for use by general practitioners; the topics selected and the levels of detail thus reflect practice in primary care. Although criteria for selecting topics are articulated, the process of selecting topics is partly subjective. In the second stage, a small taskforce consisting of four to eight general practitioners with special interest in and expertise on the topic of that guideline prepare a draft. This draft is based on a review of the available literature and current medical practice. As a result, the draft reflects not only scientific evidence, but also the consensus in the taskforce with respect to appropriate medical practice in primary care. In the third stage, a random sample of 50 Dutch general practitioners and a number of specialists review this draft. The fourth and final stage involves the authorization of the guideline by a board consisting of leading general practitioners including the chairs of the university departments of General Practice. After authorization, the guideline is published in the journal of the Dutch College of General Practitioners. After publication, the guidelines are revised at regular intervals.

Guidelines, however, have proven difficult to implement. A number of studies have shown that the existence of guidelines does not necessarily lead to the use of these guidelines by physicians. Even when authoritative guidelines are available, changing the behavior of physicians is difficult (10-13). Investigators acknowledge that the dissemination and implementation of guidelines constitutes an important research area that has to be addressed. (14-16). Dissemination of guidelines alone is not enough; it needs to be combined with an appropriate implementation strategy (3, 17). Some authors suggest that initiatives to implement guidelines must employ active educational strategies if enduring changes in attitude are to result. (18). On the other hand, some authors argue that the use of electronic patient records will provide new opportunities for decision support (14, 19-23); they argue that the integration of decision support facilities with the electronic patient record provides a natural way to integrate that support in day-to-day practice. Recently, Shiffman et al. (24) analyzed the functionality and effectiveness of computer-based guideline implementations; guideline adherence improved in 14 of 18 systems in which it was measured.

In The Netherlands, the majority of general practitioners have replaced their traditional paper-based medical record with an electronic patient record (25). These general practitioners use the computer during patient encounters to record the medical data. To take advantage of the use of electronic patient records by Dutch general practitioners, we have built the test-ordering module, BloodLink-Guideline, integrated with the electronic patient record, that supports the general practitioner in requesting blood tests. Our objective was to improve adherence to the guidelines of the Dutch College of General Practitioners by implementing a test-ordering module that provides the general practitioner with recommendations for test ordering based on these guidelines. In a randomized trial we demonstrated that BloodLink-Guideline led to a significant reduction of the number of tests ordered by the general practitioners (26).

Although the effect of BloodLink-Guideline on test-ordering behavior was unequivocal, a clear impact of BloodLink-Guideline on the volume of tests ordered is not necessarily an indication of the degree of compliance to the guidelines. In this study we focus on the compliance of the general practitioner to the recommendations for test ordering as provided by the guidelines of the

Dutch College of General Practitioners. We will first, however, briefly describe the BloodLink-Guideline module.

5.2.1 BloodLink-Guideline

By January 1996, the Dutch College of General Practitioners had published 54 guidelines covering most clinical situations in primary care. We analyzed the version of each guideline available in January 1996 (27). If the guideline contained a reference to a blood test, we determined the clinical situation in which the test should be performed (*the indication*) and the tests that should be performed in that situation (*the recommended tests*).

Of the 54 guidelines, 23 guidelines addressed blood tests and allowed us to identify the indications for those tests (27). We distinguished five categories of indications:

1. Clinical situations in which the general practitioner has a working diagnosis and subsequently uses blood tests to support or refute that diagnosis;
2. Clinical situations in which the general practitioner has established a diagnosis, and uses blood tests to investigate the underlying pathology that could be causing the disease;
3. Clinical situations in which the general practitioner is monitoring the course of a disease;
4. Clinical situations in which the general practitioner uses blood tests to select appropriate treatment;
5. Clinical situations in which the general practitioner is monitoring side effects of drugs.

BloodLink-Guideline, based on these five categories of indications and involving 68 different indications, requires a total of 37 different tests (27).

The general practitioners, using the electronic patient record, can activate BloodLink to order blood tests. BloodLink-Guideline first provides an overview of the available guidelines (Fig. 2). In The Netherlands, the names of these guidelines are familiar to general practitioners. The guidelines are published in the journals, taught in medical school, and included in mandatory

continuing medical education. We have, therefore, decided to adhere to the names of these guidelines as much as possible. The general practitioner selects the appropriate guideline, for example liver disease. A guideline may describe several different indications for requesting blood tests; for example, the guideline "blood tests and liver disease" mentions ten different indications. Once the general practitioner has selected a guideline, BloodLink-Guideline queries the general practitioner about the reasons for requesting the tests until an indication is identified. Depending on the number of indications mentioned in the guideline, the general practitioner has to answer up to three questions. When the general practitioner has, for example, selected liver disorders, the next questions deal with the disease involved (e.g., hepatitis B) and the indication (e.g., monitoring the course of hepatitis B). Optional help texts are available at each selection that explain the choices and provide the relevant sections of the guidelines. After the indication has been identified, the system proposes the relevant tests. The version of BloodLink-Guideline used during the clinical trial in the region of Delft, The Netherlands, includes, in addition to all national guidelines, three regional guidelines: anemia, AIDS, and bleeding tendency. Even with these additional guidelines, BloodLink-Guideline does not yet 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 type the initial letter of the desired test.

Guideline implementation occurs in the context of conflicting pressures for clinical autonomy and professional standardization and quality improvement. (28-30). While guidelines are explicit but crude summaries of both "state of the art" evidence-based medicine and implicit skills, they should be used not to dictate practice but to inform clinical judgment. Moreover, patients have multiple problems and often present with non-specific complaints. The indication-oriented test protocols of BloodLink-Guideline, therefore, are only a recommendation to the physician. The general practitioner makes the decision of protocol adherence. At any time, the practitioner may add tests to or remove tests from the list proposed by BloodLink. The physician thus has the freedom to deviate from the guidelines, and adapt the test ordering to the patient-specific clinical situation.

5.3 Methods

In August and September 1995, the general practitioners in the region of Delft were asked to participate in a randomized controlled trial in which we studied the impact of BloodLink-Guideline (26). A total of 62 general practitioners (46 practices) expressed interest to participate. Of these 62 general practitioners, 32 practitioners, practicing in 24 practices, were randomized to BloodLink-Guideline. During a three-month period the general practitioners were allowed to use BloodLink-Guideline in their practices. After this period, the general practitioners were asked whether they wished to start the study. One practitioner did not want to proceed; he stated that the response time of his computer had deteriorated.

The study period was March 1996 through February 1997. We logged the use of the BloodLink-Guideline software in the general practitioners office by recording the use of the software in the patients' medical records. For test ordering, physicians had the choice to use either the BloodLink-Guideline software or the traditional paper; the traditional paper order forms were available during the entire intervention period.

For all indications we counted the frequency of use and the number of tests added to or removed from the proposed test panel per practice. Protocol compliance was measured by comparing the BloodLink test recommendations with the actually ordered tests per indication. If the physician did not change the recommendations of BloodLink-Guideline, we labeled the order form as compliant. If the physician did modify the recommendations, we labeled the order form as non-compliant. The non-compliant order forms were subsequently classified into one of three categories. If the physician only added tests, we classified the order form as non-compliant by addition of tests. If the physician only removed tests, we classified the order form as non-compliant by removal of tests. If the physician both removed and added tests, we classified the order form as non-compliant by both addition and removal of tests. The main outcome measure was the percentage of order forms compliant with the recommendations for test ordering of the guidelines of the Dutch College of General Practitioners.

Guidelines are regularly updated in the light of changing medical knowledge. To assess whether non-compliance was related to a pending change in a guideline, we analyzed in October 1999 which guidelines involving test ordering had been updated after the end of the intervention period (that is, after February 28th 1997). We subsequently determined whether the updated guidelines supported the three most frequently added tests.

5.4 Results

For test ordering, the general practitioner had the choice to use either the BloodLink software or the traditional paper form. Of the 12,668 order forms of the BloodLink-Guideline group, 9,091 (72 percent of all orders) were generated using the decision-support software. The general practitioner produced 7,346 of the 9,091 forms by selecting an indication listed in BloodLink-Guideline. For these 7,346 order forms, the general practitioners used a total of 66 different indications. As shown in Table 1, twelve indications accounted for more than 80 percent of the 7,346 order forms; the most frequently used indication was "vague complaints" with 2,209 order forms (30.1 %). When the general practitioner could not find the indication, BloodLink-Guideline allowed the general practitioner to type the indication and select tests; of the 9,091 forms, the general practitioner typed an indication and selected tests in 1,745 order forms.

After selecting the indication, the general practitioner could change the recommendations of BloodLink-Guideline. Of the 7,346 order forms, 2,874 (39.1 %) were compliant with the recommendations of BloodLink-Guideline. The remaining 4,472 order forms were non-compliant. Of the 7,346 order forms, 262 (3.6 %) were non-compliant by removal of tests, 3,337 (45.4 %) were non-compliant by addition of tests, and 873 (11.9 %) were non-compliant by both removal and addition of tests. Table 2 shows, for each practice, the percentage of compliant order forms, non-compliant order forms by removal of tests, non-compliant order forms by addition of tests, and non-compliant order forms by both removal and addition of tests.

Table 1: The most frequently used indications

Indication	Frequency	Percent	Cumulative Percent
Vague complaints,	2209	30.1	30.1
Hypertension, assessing risk factors	666	9.1	39.2
Hypercholesterolemia, screening	629	8.6	47.7
Anemia, establishing diagnosis	346	4.7	52.5
Allergic rhinitis, establishing diagnosis	320	4.4	56.9
Hyperthyroidism, establishing diagnosis	313	4.3	61.2
Hypercholesterolemia, monitoring course of disease	275	3.7	64.9
Rheumatoid arthritis, establishing diagnosis	268	3.6	68.5
Infectious mononucleosis, establishing diagnosis	260	3.5	72.0
Prostate cancer, establishing diagnosis	232	3.2	75.2
Iron depletion anemia, establishing diagnosis	210	2.9	78.1
Diabetes mellitus, monitoring course of disease	155	2.1	80.2

The physician removed one or more tests in 1,135 forms (that is, 262 forms were non-compliant by removal and 873 forms non-compliant by both removal and addition); the physician removed only a single test in 762 order forms (67.1%), two tests in 285 forms (25.1 %), and three or more tests in 88 forms (7.8 %). When removing tests, the general practitioner removed on average 1.4 tests.

The physician added one or more tests in 4,210 forms (that is, 3,337 forms non-compliant by addition and 873 forms non-compliant by both removal and addition); the physician added only a single test in 1,259 order forms (29.9 %), two tests in 1,108 forms (26.3 %), and three or more tests in 1,843 forms (43.8 %). When adding tests, the general practitioner added on average 2.9 tests.

Table 2: Per practice, the compliance with the recommendations of BloodLink-Guideline.

Practice	Compliant	Non-compliant by removal of tests	Non-compliant by addition of tests	Non-compliant by both removal and addition
1	30.7%	11.3%	47.9%	10.1%
2	26.5%	6.3%	53.6%	13.7%
3	60.3%	5.0%	28.5%	6.3%
4	39.1%	7.0%	41.1%	12.9%
5	11.2%	0.6%	54.7%	33.6%
6	48.9%	2.6%	42.1%	6.4%
7	53.5%	2.3%	36.0%	8.3%
8	39.2%	1.5%	51.4%	8.0%
9	60.9%	1.1%	35.5%	2.5%
10	35.7%	2.8%	47.3%	14.2%
11	45.4%	11.3%	26.2%	17.2%
12	29.1%	1.6%	45.5%	23.8%
13	34.2%	0.3%	61.6%	3.9%
14	58.4%	0.0%	38.0%	3.6%
15	10.2%	0.7%	81.0%	8.1%
16	18.3%	0.5%	76.3%	5.0%
17	37.8%	6.1%	45.2%	10.9%
18	55.7%	3.3%	38.0%	3.0%
19	56.0%	11.0%	18.1%	14.8%
20	39.7%	2.0%	39.7%	18.3%
21	49.8%	2.8%	41.8%	5.6%
22	49.4%	2.7%	36.9%	11.0%
23	43.9%	3.3%	44.7%	8.1%
Mean	39.1%	3.6%	45.4%	11.9%

To assess if non-compliance was related to pending revision of guidelines, we analyzed which guidelines were revised after the intervention period. We found that a total of 13 guidelines were revised after the intervention period; four of these revised guidelines showed changed recommendations for test ordering: "Hypercholesterolemia", "Diabetes Mellitus", "Sore Throat", and "Hypertension". Compared to the previous guideline, the revised guideline "Hypertension" adds potassium to the diagnostic work-up of new patients; the revised guideline "Hypercholesterolemia" adds the investigation of lipids and glucose to screen for additional risk factors, the revised guideline "Sore Throat" adds a white blood cell count when suspecting leukemia or

agranulocytosis, and the revised guideline "Diabetes Mellitus" adds HbA1C in monitoring treatment and adds lipids testing in all patients.

Table 3 compares the three most frequently added tests in the non-compliant order forms with the recommendations of the updated guidelines "Hypercholesterolemia", "Diabetes mellitus", "Sore Throat" and "Hypertension". In total, the general practitioners generated 2,295 order forms by selecting an indication from these four guidelines. The GPs used indications from the guideline "Hypercholesterolemia" a total of 1,037 times. Of these 1,037 order forms, 398 (38.4 %) were compliant with the guidelines that were available during the intervention period, and 639 (61,6 %) were non-compliant. Of the 639 non-compliant order forms, 4 (0.6 %) were non-compliant by removal of tests, 608 (95.1 %) were non-compliant by addition of tests, and 27 (4.2 %) were non-compliant by both removal and addition of tests. When adding tests, the general practitioner added on average 3.0 tests. The most frequently added tests were Triglycerides, HDL-cholesterol, and Glucose; of the 639 non-compliant order forms, 509 (79.7 %) order forms involved adding Triglycerides, 506 (79.2 %) involved adding HDL-cholesterol and 186 (29.1%) adding Glucose.

Table 3: The three most frequently added tests in the non-compliant order forms compared with the recommendations of the updated guideline.

Guideline	Non-Compliant forms	Test added (% of Non-Compliant forms)	Recommended in updated guideline
Hypercholesterolemia	639	Triglycerides (79,7)	No
		HDL-cholesterol (79,2)	Yes
		Glucose (29,1)	Yes
Hypertension	323	K (33,4)	Yes
		Hb (29,1)	No
		Triglyceride (26,9)	No
Diabetes mellitus	226	HbA1C (71,2)	Yes
		Triglyceride (19,9)	Yes
		HDL-cholesterol (19,0)	Yes
Sore throat	182	BSE (70,9)	No
		Hb (48,4)	No
		Glucose (24,7)	No

The general practitioners used indications from the guideline "Hypertension" a total of 666 times. Of these 666 order forms, 343 (51.5 %) were compliant and 323 (48.5%) order forms were non-compliant. Of the 323 non-compliant order forms, 26 (8.0 %) were non-compliant by removal of tests, 256 (79.3 %) were non-compliant by addition of tests, and 41 (12.7 %) were non-compliant by both removal and addition of tests. When adding tests, the general practitioner added on average 2.8 tests. The most frequently added tests were Potassium, Hb, and Triglycerides; of the 323 non-compliant order forms, 108 (33.4 %) order forms involved adding Potassium, 94 (29.1 %) involved adding Hb, and 87 (26.9 %) adding Triglycerides.

The general practitioners used indications from the guideline "Diabetes Mellitus" a total of 332 times. Of these 332 order forms, 106 (31.9 %) were compliant and 226 (68.1 %) were non-compliant. Of the 226 non-compliant order forms, 4 (1.8 %) were non-compliant by removal of tests, 195 (86.3 %) were non-compliant by addition of tests, and 27 (11.9 %) were non-compliant by both removal and addition of tests. When adding tests, the general practitioner added on average 2.5 tests. The most frequently added tests were HbA1C, Triglycerides and HDL-Cholesterol; of the 226 non-compliant order forms, 161 (71.2 %) order forms involved adding HbA1C, 45 (19.9 %) involved adding Triglycerides and 43 (19.0 %) adding HDL-cholesterol.

The general practitioners used indications from the guideline "Sore Throat" a total of 260 times. Of these 260 order forms, 78 (30.0 %) were compliant and 182 (70.0 %) order forms were non-compliant. Of the 182 non-compliant order forms, 4 (2.2 %) were non-compliant by removal of tests, 159 (87.4 %) were non-compliant by addition of tests, and 19 (10.4 %) were non-compliant by both removal and addition of tests. When adding tests, the general practitioner added on average 2.8 tests. The most frequently added tests were BSE, Hb, and Glucose; of the 182 non-compliant order forms, 129 (70.9 %) order forms involved adding BSE, 88 (48.4 %) involved adding Hb and 45 (24.7 %) adding Glucose.

5.5 Discussion

Researchers have repeatedly argued that test-ordering behavior of physicians lacks efficiency, resulting in excessive laboratory utilization. Literature documents many attempts to change the test-ordering behavior of physicians. In The Netherlands, the ordering of blood tests has been the subject of a number of studies that attempted to reduce the number of blood tests ordered by the general practitioner (31-38). In a previous study, we reported that introducing indication-oriented test panels based on the guidelines of the Dutch College of General Practitioners reduces the number of tests ordered (26). The observed reduction of the number of tests requested by the physician, however, does not necessarily mean that the physicians adhere to the protocols. In this study, therefore, we focused on protocol adherence.

Although BloodLink-Guideline supports 66 indications, 12 indications accounted for more than 80% of the general practitioners' use of the system. The most frequently used indication was "vague complaints", reflecting the morbidity in primary care. Primary care is characterized by its role in diagnosing undifferentiated problems. In primary care, practitioners are often confronted with initial signs and symptoms presenting minor illness, not requiring medical intervention, or early stages of diseases. The morbidity seen by a general practitioner, therefore, will differ significantly from the morbidity in secondary and tertiary care. The fact that 25% of all blood tests are performed with vague complaints as indication is therefore not surprising and consistent with other studies in Dutch primary care (37, 39).

Our study shows that removing tests from the recommendations of the guidelines is rare compared to adding tests. General practitioners seem to rely on the guideline-based test recommendations as the basis for test ordering in daily practice. We hypothesize that the general practitioner accepts the indication-based test recommendations as a minimum for diagnosing undifferentiated problems at the first point of care. Although the introduction of BloodLink-Guideline resulted in a clear reduction of the number of tests ordered (26), this study shows that a complete compliance to the guidelines would have resulted in a still larger reduction.

In our study, the addition of tests is the main cause of non-compliance. Non-compliance, however, does not necessarily indicate poor performance. The first possible reason for adding tests is the fact that, in a primary care setting, patients may have other diseases (e.g., chronic diseases such as diabetes mellitus) that require periodic monitoring; the fact that blood tests will be performed may prompt the general practitioner to add tests.

A second reason for adding tests could be the fact that the indications show a certain degree of overlap. The revised guideline "Sore Throat" includes recommendations for test ordering to exclude infectious mononucleosis and leukemia as underlying pathology for sore throat. As shown in Table 3, the most frequently added tests on the non-compliant order forms from the guideline "Sore Throat" are BSE, Hb and glucose. The guideline "Vague Complaints", however, includes BSE, Hb and glucose. Vague complaints are well known initial symptoms for both infectious mononucleosis and leukemia. Possibly the general practitioners selecting the guideline "Sore Throat" considered "Vague Complaints" as indication for test ordering as well.

A third possible explanation for adding tests is a defensive attitude. Defensive testing is, also in Dutch family practice, a well-established phenomenon (40, 41). The frequency in which the general practitioner adds tests could be the effect of the general practitioners' uncertainty and defensive behavior.

Our study, however, shows another reason for adding tests: anticipating pending changes in the guidelines. For the guidelines that had been revised after the intervention period, we compared the three most frequently added tests in the non-compliant order forms with the recommendations of the updated guideline. Many of the modifications that caused the order form to be non-compliant, however, are supported by the revised guidelines. For example, HDL-cholesterol, added in 79.2 percent of the non-compliant order forms, is included in the recommendations of the revised guideline "Hypercholesterolemia". Likewise, HbA1C, added in 71.2 percent of the non-compliant order forms, is included in the recommendations of the revised guideline "Diabetes Mellitus". Apparently, general practitioners are aware of the pending changes in the guidelines and anticipate by adding tests. Evidence-based medicine requires that guidelines be revised in the light of the available randomized clinical trials (42). New trials that first appear in medical

journals are read by physicians, and may subsequently result in revision of guidelines. Adoption of recent knowledge into daily practice could therefore precede dissemination of revised guidelines.

Absence of protocol adherence must be interpreted carefully. When investigating protocol adherence, physicians applying most recent knowledge may show poor adherence to protocols when compared to physicians applying available guidelines. When viewing protocol adherence as a goal in itself, however, explaining the deviations from protocols may take the form of a debate on the barriers that prevent the protocol from being used. Recently, Cabana et al., for example, reported a variety of barriers to physician guideline adherence, including lack of awareness, lack of familiarity, lack of agreement, lack of self-efficacy, lack of outcome expectancy, and inability to overcome the inertia of previous practice (43). They argue that the interpretation of successful interventions to improve physician adherence to guidelines should be reviewed carefully, while strategies successful in one setting may be less useful in a setting where barriers differ. When protocol adherence is viewed as a goal in itself, applying the most recent knowledge could be interpreted as a "barrier" to protocol adherence. Disregarding the dynamic nature of guideline development may lead to pointlessly focusing on barriers to physician guideline adherence.

5.6 References

1. Zaat JOM. De macht der gewoonten: Over de huisarts en zijn laboratorium onderzoek [Thesis]. Amsterdam: Free University Amsterdam; 1991 *(On the General Practitioner and his laboratory test ordering. In Dutch, English Summary).*
2. van der Weijden T, Dansen A, Schouten BJ, Knottnerus JA, Grol RP. Comparison of appropriateness of cholesterol testing in general practice with the recommendations of national guidelines: an audit of patient records in 20 general practices. Quality of Health Care 1996;5:218-22.
3. Van Walraven C, Goel V, Chan B. Effect of population-based interventions on laboratory utilization: a time-series analysis. Journal of the American Medical Association 1998;280:2028-33.
4. Van Walraven C, Naylor CD. Do we know what inappropriate laboratory utilization is? A systematic review of laboratory clinical audits. Journal of the American Medical Association 1998;280:550-558.
5. Hindmarsh JT, Lyon AW. Strategies to promote rational clinical chemistry test utilization. Clinical Biochemistry 1996;29:291-9.
6. Mutimer D, McCauley B, Nightingale P, Ryan M, Peters M, Neuberger J. Computerised protocols for laboratory investigation and their effect on use of medical time and resources. Journal of Clinical Pathology 1992;45:572-4.
7. Wong ET, Lincoln TL. Ready! Fire! ...Aim. Journal of the American Medical Association 1983;250(18):2510-2513.
8. Kelly JT. Role of clinical practice guidelines and clinical profiling in facilitating optimal laboratory use. Clinical Chemistry 1995;41:1234-1236.
9. Thomas S. Standard setting in The Netherlands: impact of the human factor on guideline development. British Journal of General Practice 1994;44:242-3.
10. Lomas J, Anderson GM, Domnick-Pierre K, Vayda E, Enkin MW, Hannah WJ. Do practice guidelines guide practice? The effect of a consensus statement on the practice of physicians. New England Journal of Medicine 1989;321:1311-1315.
11. Grol R. Development of guidelines for general practice care. British Journal of General Practice 1993;43:146-51.

12. Grimshaw JM, Russell IT. Effect of clinical guidelines on medical practice: A systematic review of rigorous evaluations. The Lancet 1993;342:1317-1322.
13. Grol R. National standard setting for quality of care in general practice: attitudes of general practitioners and response to a set of standards. British Journal of General Practice 1990;40:361-4.
14. Elson RB, Connelly DP. Computerized patient records in primary care. Their role in mediating guideline-driven behavior change. Archives of Family Medicine 1995;4:698-705.
15. Shiffman RN, Brandt CA, Liaw Y, Corb GJ. A design model for computer-based guideline implementation based on information management services. Journal of the American Medical Informatics Association 1999;6:99-103.
16. Lomas J. Words without action? The production, dissemination and impact of consensus recommendations. Annual Review of Public Health 1991;12:41-65.
17. Forrest D, Hoskins A, Hussey R. Clinical guidelines and their implementation. Postgraduation Medicin 1996;72:19-22.
18. Onion CW, Bartzokas CA. Changing attitudes to infection management in primary care: a controlled trial of active versus passive guideline implementation strategies. Family Practice 1998;15:99-104.
19. Tierney WM, Overhage JM, Takesue BY, Harris LE, Murray MD, Vargo DL, et al. Computerizing guidelines to improve care and patient outcomes: the example of heart failure. Journal of the American Medical Informatics Association 1995;2:316-322.
20. Henry SB, Douglas K, Galzagorry G, Lahey A, Holzemer WL. A template-based approach to support utilization of clinical practice guidelines within an electronic record. Journal of the American Medical Informatics Association 1998;5:237-244.
21. Balas EA, Austin SM, Mitchell JA, Ewigman BG, Bopp KD, Brown GD. The clinical value of computerized information services. A review of 98 randomized clinical trials. Archives of Family Medicine 1996;5:271-8.
22. Hunt DL, Haynes RB, Hanna SE, Smith K. Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. Journal of the American Medical Association 1998;15:1339-46.
23. Lobach DF, Hammond WE. Computerized decision support based on a clinical practice guideline improves compliance with care standards. American Journal of Medicin 1997;102:89-98.

24. Shiffman RN, Liaw Y, Brandt CA, Corb GJ. Computer-based guideline implementation systems: a systematic review of functionality and effectiveness. Journal of the American Medical Informatics Association 1999;6:104-14.
25. Van der Lei J, Duisterhout JS, Westerhof HP, Van der Does E, Cromme PVM, Boon WM, et al. The introduction of computer-based patient records in the Netherlands. Annals of Internal Medicine 1993;119:1036-1041.
26. van Wijk MAM, van der Lei J, Mosseveld BMTh, Bohnen AM, Bemmel JH. Assessment of Decision Support for Blood Test Ordering in Primary Care. Submitted for publication 1999.
27. Van Wijk MA, Bohnen AM, Van der Lei J. Analysis of the practice guidelines of the Dutch College of General Practitioners with respect to the use of blood tests. Journal of the American Medical Informatics Association 1999;6:322-331.
28. Grol R, Dalhuijsen J, Thomas S, Veld C, Rutten G, Mokkink H. Attributes of clinical guidelines that influence use of guidelines in general practice: observational study. British Medical Journal 1998;317:858-861.
29. Langley C, Faulkner A, Watkins C, Gray S, Harvey I. Use of guidelines in primary care--practitioners' perspectives. Family Practice 1998;15:105-11.
30. Grol R, Wensing M. Implementation of quality assurance and medical audit: general practitioners' perceived obstacles and requirements. British Journal of General Practice 1995;45:548-52.
31. Bugter-Maessen AM, Winkens RA, Grol RP, Knottnerus JA, Kester AD, Beusmans GH, et al. Factors predicting differences among general practitioners in test-ordering behavior and in the response to feedback on test requests. Family Practice 1996;13:254-8.
32. Geldrop WJ, Lucassen PLBJ, Smithuis LOMJ. Een probleemgeoriënteerd aanvraagformulier voor laboratoriumonderzoek. Huisarts en Wetenschap 1992;35:192-197.
33. Winkens RAG, Pop P, Grol RPTM. Effect of feedback on test-ordering behavior of general practitioners. British Medical Journal 1992;304:1093-1097.
34. Winkens RA, Bugter-Maessen AM, Grol RP, Kester AD, Beusmans GH, Knottnerus JA. Randomised controlled trial of routine individual feedback to improve rationality and reduce numbers of test requests. The Lancet 1995;25:498-502.
35. Winkens RAG, Pop P, Grol RP, Bugter-Maessen AM, Kester AD, Beusmans GH, et al. Effects of routine individual feedback over nine

years on general practitioners' requests for tests. British Medical Journal 1996;24:490.

36. Kluijt I, Zaat JOM, Van der Velden J, van Eijk JTM, Schellevis FG. Voor een prikje: Huisarts en bloedonderzoek. Huisarts en Wetenschap 1991;34:67-71 *(The general practitioner and bloodtests. In Dutch, English abstract.).*
37. Dijksterhuis PH, Van Boven C, Lamberts H. Waarom aanvullend onderzoek? De functie van het aanvullend onderzoek door de huisarts. Huisarts en Wetenschap 1994;37:467-472 *(The role of test-ordering in general practice. In Dutch, English Abstract.).*
38. Zaat JO, Van Eijk JT, Bonte HA. Laboratory test form design influences test ordering by general practitioners in the Netherlands. Medical Care 1992;30:189-198.
39. Foets M, Van der Velden J, De Bakker DH. Dutch National Study of General Practice: Utrecht, NIVEL; 1992.
40. Van Boven K, Dijksterhuis P, Lamberts H. Defensive testing in Dutch family practice. Is the grass greener on the other side of the ocean? Journal of Family Practice 1997;44:468-72.
41. Zaat JOM. General practitioners' uncertainty, risk preference, and use of laboratory tests. Medical Care 1992;30(9):846-854.
42. Davis DA, Taylor-Vaisey A. Translating guidelines into practice. A systematic review of theoretic concepts, practical experience and research evidence in the adoption of clinical practice guidelines. CMAJ 1997;157:408-16.
43. Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH, Abboud PC, et al. Why don't physicians follow clinical practice guidelines? Journal of the American Medical Association 1999;282:1458-63.

Chapter 6

General Discussion and Suggestions for Future Research

6.1 Introduction

The overall objective of this thesis was to assess and compare the effect of two methods of influencing blood test ordering behavior of Dutch general practitioners. Within the overall objective we also studied if a decision support system is able to implement the practice guidelines of the Dutch College of General Practitioners into daily practice. To achieve this objective we analyzed the consistency among practice guidelines of the Dutch College of General Practitioners with respect to the use of blood tests, designed the decision support system BloodLink, conducted a randomized trial to assess the impact on the volume of test ordering, and determined the compliance of Dutch general practitioners to the recommendations for test ordering as defined in the guidelines of the Dutch College of General Practitioners. Separate conclusions can be drawn from different parts of our study, but at the same time new questions arise. We will now discuss those conclusions and give suggestions for future research that might give an answer on the newly raised questions.

6.2 Consistency and Timeliness of Guidelines

Our analysis shows that the majority of the guidelines of the Dutch College of General Practitioners provide clear and unambiguous recommendations for blood test ordering in primary care. We discovered, however, some incomplete recommendations and inconsistencies. Given that inconsistencies were found, we recommend that organizations that maintain a set of guidelines should make available to physicians a list of known inconsistencies among those guidelines. In addition, all new guidelines should be tuned with other available guidelines before publishing to avoid inconsistencies among guidelines. In the Netherlands, the process of developing guidelines consists of various steps to achieve a good balance between evidence based guidelines and guidelines that are acceptable in daily practice (1). In addition to *preparation, draft guidelines, testing, authorization, formatting,* we recommend *tuning,* before *dissemination and implementation* as an essential step to take for attaining the intended balance. Tuning guidelines might lead to

more concordance between guidelines, inducing unambiguous interpretation of guidelines, which in turn may stimulate physicians' adherence with guidelines.

Our study also illustrates the consequences of the dynamic nature of guideline development on guideline implementation and protocol adherence in daily practice. Evidence-based medicine requires that guidelines be revised in the light of the available randomized clinical trials (2, 3). New trials appearing in medical journals may have an impact on medical practice before resulting in the revision of guidelines. Adoption of recent knowledge into daily practice could therefore precede dissemination of revised guidelines. As a result, physicians applying most recent knowledge may show poor adherence to protocols when compared to physicians applying available guidelines. In our study, we also address the issue of compliance to the guidelines. We showed that many of the modifications that caused the order forms to be non-compliant are supported by the revision of guidelines after the intervention period. In these cases, the general practitioner is actually anticipating changes in the guidelines. We therefore recommend the Dutch College of General Practitioners to reconsider the method and frequency of revising guidelines.

Internet technology could accelerate the process of reviewing recent randomized clinical trials and developing or modifying guidelines. Moreover, the technology could facilitate the international collaboration when developing guidelines. Recently in an invitational workshop "Toward a Sharable Guideline Representation" (held in Boston, MA, March 3-4, 2000), stakeholders from government, academia, professional specialty organizations, health care provider organizations, insurers, and industry, from 12 countries focused on: "developing an approach to ensuring that clinical practice guidelines can be designed in a more structured, standardized fashion, that enables them to be shared among developers and users, and that has sufficient specification to enable the guidelines to be incorporated into a variety of kinds of information systems applications" (4). The workshop resulted in establishing electronic forums dealing with specific issues like functional requirements, modeling and representation, infrastructure and organization and processing of guidelines. Initiatives like this could be the onset of web based sharable guidelines maintained by authoritative organizations. We believe that in the near future decision-support systems embedded in a

computer-based patient record can be updated with guidelines available on public web sites (5). As a result, the time required for revising and disseminating guidelines based on the most recent evidence will be shorter. The finding of our study that general practitioners anticipate on pending changes in the guidelines underscores the time delay in the current paper-based procedures and the need to accelerate the inclusion of new medical knowledge into guidelines.

6.3 Decision Support Driven by Physician's Interpretation of Patient Data

When designing the system, we had to determine whether the decision support is based on the patient's symptoms or on the general practitioner's indications. For the general practitioner, these two methods will result in two different systems. If the objective of the system is to select the appropriate test given the indication, the general practitioner has to answer questions about his or her indication and translate the patient's condition to a specific indication. If the objective is to support the identification of the indication, the decision support system will require detailed information about the patient's condition. This approach requires the physician to enter patient data. Based on the available data, the system could generate indications, select among these, and prepare a recommendation for test ordering. If the identification of the indication is based on the data in the electronic patient record, the accuracy of that data is of critical importance. The levels of accuracy in electronic patient records, however, have been reported as varying (6). In addition, the identification of indications requires a formal decision model (for example, a Baysian model) that translates the patient's symptoms to indications (7).

We decided to build a system that requests from the general practitioner the indication, BloodLink-Guideline. This decision is not only based on the fact that the guidelines provide recommendations on the level of indication. We also believe that especially general practitioners are able to translate the often-complex presentation of patients' complaints to well-defined indications. Computers are only able to deal with those parts of the patient-physician

encounter that can be translated to objective facts and numbers; as a result, decision support systems can only deal with a very limited segment of reality. Other investigators have lamented the fact that decision support systems tend to ignore the intellect of the physician, and leave the physician with a sense of losing control (8, 9). We believe that in the area of the initial interpretation of the symptoms of the patient the role of a decision support system should be very limited. Further research must clarify if this assumption is correct.

6.4 Ease of Introduction of Guidelines in Daily Practice

The results of our study clarify that little effort was needed to introduce the recommendations for test ordering of the guidelines of the Dutch College of General Practitioners. In the light of the difficulties others have experienced in attempting to change physicians' patterns of care the ease of introduction of BloodLink in daily practice is a remarkable finding of our study (10). Although no training program (only a short instruction was given) accompanied the introduction of the BloodLink software and the familiar paper forms were still available during the intervention period, the majority of the orders were placed using BloodLink.

A first possible reason for the ease of the introduction is that Dutch general practitioners are used to using computers to maintain their patient records. By integrating the module BloodLink with the computerized patient record, using the decision support system possibly did not interfere much with daily workflow of the participating physicians. The results of our study underscores the potential advantage of computerized patient records as a vehicle for changing physicians' behavior and may encourage the use of computerized patient records to enter patient data during patient encounters (11).

A second possible explanation is that participating physicians mainly adopted BloodLink, because it facilitates the test-ordering procedure. Designing the decision support system BloodLink, we wanted the system to be integrated in daily practice, and relieve the physician of routines. At least it should not impede the daily workflow of participating physicians. BloodLink prints a

patient-specific blood order form that includes the necessary patient data (such as name, age, address, etc.), the tests ordered and the specific instructions for the laboratory. In addition the system updates the patient record to show which tests have been ordered. BloodLink's use of already entered administrative data eliminates the need for the general practitioner to re-enter these data. As a result, using BloodLink also has a timesaving aspect. We did not measure the actual time required to fill in the electronic order form. We, therefore, do not know whether the timesaving aspect of BloodLink outweighs the time required to select the appropriate indication. The two versions of BloodLink were developed to conduct a randomized trial. In the development of BloodLink, however, we emphasized integration with the daily workflow. Further research must clarify if trials that facilitate daily workflow without compromising theoretical assumptions of the trial will be most successful in changing physicians' behavior (12).

6.5 Comparing the Effect of Two Methods of Influencing Blood Test-ordering Behavior of Dutch General Practitioners

The fact that in our study 20 tests accounted for 80 percent of the total number of tests ordered supports the notion that a limited number of tests satisfies the requirements for test ordering in most situations in primary care (13). BloodLink-Guideline, based on five categories of indications and involving 68 different indications (14), requires a total of 37 different tests. Although BloodLink-Guideline supports the use of 37 tests as compared to the 15 alphabetically ordered tests listed in BloodLink-Restricted, the use of BloodLink-Guideline results in a much larger reduction in ordered 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, based on medical knowledge related to a specific indication. BloodLink-Guideline enables physicians to apply the medical knowledge of guidelines, whereas BloodLink-Restricted applies the notion of an initially limited set of tests that should fit most circumstances. Our study indicates that, in the domain of 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 merely reducing the form to a limited set of tests. Future research will have to evaluate whether these findings are limited to the domain of blood test ordering, or whether they can be duplicated in other domains.

6.6 Adherence to Guidelines

Twelve indications accounted for more than 80 percent of the indication-oriented order forms created by BloodLink-Guideline. The most frequently used indication for test ordering was "vague complaints" (30.1 % of all indications) reflecting the morbidity in primary care. Thirty-nine percent of the indication-oriented order forms were compliant with the recommendations for test ordering provided by the guidelines of the Dutch College of General Practitioners. Removing tests is rare compared to adding tests. Many of the modifications that caused the order form to be non-compliant are supported by revisions of guidelines after the intervention period. General practitioners rely on guideline-based test recommendations as a basic minimum for test ordering in daily practice but at the same time anticipate on pending revision of guidelines. Disregarding this aspect might lead to pointlessly focusing on barriers to physician guideline adherence (15). We conclude that if the general practitioner would completely adhere to the recommendations for test ordering of the guidelines, a still greater reduction would be attained. Further research will have to clarify whether our belief that unnecessary tests are eliminated is correct.

6.7 Limitations

The first limitation of our study is the fact that all participating general practitioners work in the Delft region. As a result, we do not know if the findings of this study can be generalized to the whole country.

Second, we did not include in our trial a pre-intervention period in which we only recorded the indications for test ordering. The reason not to include such a pre-intervention period is the fact that recording indications constitutes an intervention in itself. As a result, we do not know the protocol adherence prior to intervention. We could have included a control group in which we only recorded the indications for test ordering. Initial power calculations, however, showed that the number of general practitioner was too small for a third trial arm in the Delft region. In retrospect, the impact of the BloodLink software was such that a third trial arm could have been formed.

We have started a second trial in which we address these limitations. We are in the initial phase of a study to assess the effect of indication-oriented decision support on test-ordering behavior of 250 Dutch general practitioners. This study will involve general practitioners from several regions of the country, and include a control group that records the indications for test ordering without the use of decision support software.

6.8 Closing Remarks

Closing the final chapter of this thesis we conclude that

- the guidelines of the Dutch College of General Practitioners contain concrete and specific recommendations for test ordering;
- in the area of the initial interpretation of the symptoms of the patient, the role of a decision support system should be very limited;
- decision support based on guidelines is more effective in changing blood test-ordering behavior than decision support based on initially displaying a limited number of tests;
- decision support systems can be effective in introducing guidelines in primary care;
- general practitioners rely on guideline-based test recommendations as a basic minimum for test ordering in daily practice but at the same time anticipate on pending revision of guidelines.

6.9 References

1. Grol R, Thomas S, Roberts R. Development and implementation of guidelines for family practice: lessons from The Netherlands. Journal of Family Practice 1995;40:435-9.
2. Davis DA, Taylor-Vaisey A. Translating guidelines into practice. A systematic review of theoretic concepts, practical experience and research evidence in the adoption of clinical practice guidelines. CMAJ 1997;157:408-16.
3. Shaneyfelt TM, Mayo-Smith MF, Rothwangl J. Are guidelines following guidelines? The methodological quality of clinical practice guidelines in the peer-reviewed medical literature. Journal of the American Medical Association 1999;281:1900-5.
4. Greenes RA. An Invitational Workshop: Towards Representations for Sharable Guidelines. http://www.glif.org/
5. Sanders GD, Nease RFJ, Owens DK. Design and pilot evaluation of a system to develop computer-based site-specific practice guidelines from decision models. Medical Decision Making 2000;20:145-59.
6. Hogan WR, Wagner MM. Accuracy of data in computer-based patient records. Journal of the American Medical Informatics Association 1997;4:342-55.
7. Miller PL, Frawley SJ. Trade-offs in producing patient-specific recommendations from a computer-based clinical guideline: a case-study. Journal of the American Medical Informatics Association 1995;2:238-242.
8. Miller RA, Masarie FE. The demise of the Greek oracle model for medical diagnosis systems. Methods of Information in Medicine 1990;29:1-2.
9. Taylor TR. The computer and clinical decision-support systems in primary care. Journal of Family Practice 1990;30((2)):137-140.
10. Wyszewianski L, Green LA. Strategies for changing clinicians' practice patterns. A new perspective. Journal of Family Practice 2000;49:461-4.
11. Van Bemmel JH, Van Ginneken AM, Van der Lei J. A progress report on computer-based patient records in Europe. In: Detmer D, Steen EB, editors. The computer-based patient record. Washington DC: National Academy Press; 1997. p. 21-43.
12. Rogers S, Humphrey C, Nazareth I, Lister S, Tomlin Z, Haines A. Designing trials of interventions to change professional practice in

primary care: lessons from an exploratory study of two change strategies. British Medical Journal 2000;320:1580-3.

13. Zaat JO, Van Eijk JT, Bonte HA. Laboratory test form design influences test ordering by general practitioners in the Netherlands. Medical Care 1992;30:189-198.
14. Van Wijk MA, Bohnen AM, Van der Lei J. Analysis of the practice guidelines of the Dutch College of General Practitioners with respect to the use of blood tests. Journal of the American Medical Informatics Association 1999;6:322-331.
15. Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH, Abboud PC, et al. Why don't physicians follow clinical practice guidelines? Journal of the American Medical Association 1999;282:1458-63.

Summary

Summary

In The Netherlands three to four percent of patients' encounter with the general practitioner result in ordering of blood tests. Dutch investigators report a lack of general practitioners' knowledge concerning the indications for blood tests leading to inappropriate and inadequate use of diagnostic tests. Influencing test-ordering behavior of Dutch general practitioners has been the objective of many studies. Three methods have proven to be effective in changing test-ordering behavior. Personal feedback, studied by Pop and Winkens, restricting the number of choices presented to the general practitioners on the order form, studied by Zaat, and the introduction of indication-oriented order forms based on guidelines, studied by van Geldrop, Smithuis, and van Gend all proved to be effective. Which of these methods is most effective remains unknown; randomized trials comparing these methods have never been conducted. The availability of guidelines of the Dutch College of General Practitioners and the fact that almost all Dutch general practitioners replaced their paper patient records by computer-based patient records creates new opportunities to introduce guideline-based decision support in daily practice.

The objectives of this current thesis were to study the consistency of the guidelines of the Dutch College of general practitioners with respect to recommendations for test ordering, the requirements for a decision support system for test ordering, to be integrated in general practice, the influence of a guideline based decision support system on test-ordering behavior of general practitioners, and the compliance of general practitioners to a decision support system for test ordering.

Consistency of the Guidelines

In *Chapter 2*, we analyzed the practice guidelines of the Dutch College of General Practitioners, published until January 1st 1998, with respect to the use of blood tests. We evaluated 64 practice guidelines of the Dutch College of General Practitioners. For each of the guidelines, we analyzed each sentence that contained a reference to a blood test to determine the clinical situation in

which the test should be performed (*the indication*), and to determine the tests that should be performed in that situation (*the recommended tests*). Twenty-seven practice guidelines mentioned blood tests. Of these twenty-seven guidelines, three explicitly recommended *not* to request blood tests. Of the twenty-seven guidelines, twenty-three allowed us to identify indications and recommended tests. We distinguished five different categories of indications: *establishing a working diagnosis, investigating underlying pathology, monitoring the course of a disease, identifying therapy-influencing factors,* and *monitoring the side effects of drugs*. Although some incomplete recommendations and inconsistencies were discovered, we conclude that the majority of the guidelines provide clear and unambiguous recommendations for blood test ordering in primary care.

Requirements for a Decision Support System for Test Ordering

After we concluded that the majority of the guidelines provide clear and unambiguous recommendations for blood test ordering in primary care, we commenced to build a decision support system for test ordering. Building a system to change test-ordering behavior requires us to select a method we will follow when providing support. We decided to use two methods: the restricted order form method and the indication-oriented order form. To study these two methods for changing test-ordering behavior, we developed two versions of the decision support system BloodLink (described in *Chapter 3*). The first version, *BloodLink-Restricted*, is based on the notion of restricting the number of choices presented to the general practitioner. The second version, *BloodLink-Guideline* is based on the recommendations for test ordering as provided by the practice guidelines of the Dutch College of General Practitioners. BloodLink-Restricted is based on providing the general practitioner with an electronic version of a restricted order form that offers the general practitioner a list of 15 alphabetically ordered tests. These are the 15 tests that were judged by Zaat to be the most relevant in primary care. The only difference between the two versions of BloodLink is the method used to present the initial set of tests to the general practitioner. In all other respects, the two versions of the system are identical: the same integration with the

computer-based patient record, the same layout of the screens, the same abbreviations of the tests, the same mechanism by which the general practitioner can add or remove tests, the same form printed, and the same notes left in the medical record. Implementation of both versions of BloodLink allowed us to study the differences between the two methods.

The Influence of BloodLink-Guideline on Test-Ordering Behavior

To compare the effect of two methods for changing blood test-ordering behavior, after stratification by single-handed practices and group practices, 44 primary care practices of 60 Dutch general practitioners in the region Delft were randomly assigned to BloodLink-Restricted, or to BloodLink-Guideline, (described in *Chapter 4*). The intervention period was March 1996 through February 1997. The main outcome measure was the average number of blood tests ordered per order form per practice during intervention. Both approaches resulted in a decrease in the average number of tests ordered per order form when comparing the intervention period with the two years preceding the intervention: a 12 percent reduction in the BloodLink-Restricted group ($p=0.001$) and a 29 percent reduction in the BloodLink-Guideline group ($p<0.001$). General practitioners who had access to decision support based on guidelines requested on average 20 % fewer tests (5.5 tests versus 6.9 tests, respectively; Mann-Whitney test $p=0.003$, $N=44$) than general practitioners with access to decision support based on a form that initially displays a limited number of tests. We conclude that decision support based on guidelines is more effective in changing blood test-ordering behavior than merely reducing the number of test options. This study showed that BloodLink-Guideline was used for the majority of test ordering. We also conclude therefore that decision support systems are an effective method for introducing guidelines in primary care. In view of the little effort that was needed for the introduction of BloodLink in daily practice, the changes we found in test-ordering behavior could well be replicated elsewhere in primary care practices using computerized patient records

The Compliance of General Practitioners to BloodLink-Guideline

Although the effect of BloodLink-Guideline on test-ordering behavior was unequivocal, a clear impact of BloodLink-Guideline on the volume of tests ordered is not necessarily an indication of the degree of compliance to the guidelines. We studied, therefore, the compliance of the general practitioner to the recommendations of the test-ordering module BloodLink-Guideline (described in *Chapter 5*). Compliance was expressed as the percentage of order forms per practice and per indication that follow the recommendations for test ordering of the guidelines of the Dutch College of General Practitioners. The study was conducted from March 1996 through February 1997. To assess if non-compliance was related to pending revision of guidelines, we analyzed which guidelines had been revised after the intervention period and compared the three most frequently added tests in the non-compliant order forms with the recommendations of the updated guideline. Thirty-nine percent of the indication-oriented order forms were compliant. Removing tests was rare compared to adding tests. The most striking finding was that many of the modifications that caused the order form to be non-compliant were supported by revisions of guidelines after the intervention period. We conclude that general practitioners rely on guideline-based test recommendations as a basic minimum for test ordering in daily practice but at the same time anticipate on pending revision of guidelines. The results of this study may encourage the use of computer-based patient records to enter patient data during patient encounters.

Discussion

We conclude (in Chapter 6) that the guidelines of the Dutch College of General Practitioners contain concrete and specific recommendations for blood test ordering for specific indications. Based on this analysis, we developed the decision support system BloodLink. By asking the general practitioner to identify the indication for test ordering, we limited the role of BloodLink to selecting the test for a specific indication. Blood test ordering

based on the guidelines of the Dutch College of General Practitioners results in a larger reduction of the number of tests ordered than test ordering based on an initially limited set of 15 blood tests relevant for general practice. BloodLink-Guideline implements the guidelines of the Dutch College of General Practitioners in daily practice. General practitioners rely on guideline-based test recommendations as a basic minimum for test ordering in daily practice but at the same time anticipate on pending revision of guidelines. We showed that many of the modifications that caused the order forms to be non-compliant are supported by the revision of guidelines after the intervention period. We therefore recommend the Dutch College of General Practitioners to reconsider the method and frequency of revising guidelines

Samenvatting

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Door Nederlandse huisartsen wordt in drie tot vier % van de spreekuurcontacten bloedonderzoek aangevraagd. Uit de literatuur is bekend dat huisartsen over onvoldoende kennis beschikken over de eigenschappen van verschillende tests en over de indicaties voor het doen van bloedonderzoek. Dit kan aanleiding geven tot het onjuist toepassen van laboratoriumonderzoek. In verschillende studies is geprobeerd het aanvraaggedrag van huisartsen in gunstige zin te veranderen. Drie methoden bleken effectief: individuele feedback op het aanvraaggedrag (onderzocht door Pop en Winkens), introductie van een aanvraagformulier met 15 voor de huisartsenpraktijk relevante bepalingen (onderzocht door Zaat) en toepassen van een op een tweetal standaarden van het Nederlands Huisartsen Genootschap (NHG) gebaseerd, probleem-georiënteerd aanvraagformulier (onderzocht door van Geldrop, Smithuis en van Gend). Welk van deze methoden het aanvraaggedrag het meest beïnvloedt is onbekend, omdat tot nu toe de methoden niet onderling vergeleken zijn door middel van gerandomiseerd onderzoek.

De publicatie van NHG-standaarden, die een hoge mate van acceptatie kennen, en het gegeven dat bijna alle Nederlandse huisartsen gebruik maken van een elektronisch patiëntendossier bieden de mogelijkheid om richtlijnen en protocollen in de dagelijkse praktijk te implementeren met behulp van beslissingondersteunende modules.

Dit proefschrift richt zich op de volgende onderzoeksdoelen: de samenhang tussen de verschillende standaarden van het NHG voor wat betreft adviezen voor bloedonderzoek, de voorwaarden waaraan een aanvraagmodule moet voldoen om door de huisarts in de dagelijkse praktijk gebruikt te kunnen worden, de invloed van een op NHG-standaarden gebaseerde laboratorium-module op het aanvraaggedrag van huisartsen, de mate waarin huisartsen de adviezen voor bloedonderzoek uit de NHG-standaarden ook daadwerkelijk opvolgen.

Samenhang tussen de NHG-standaarden

Allereerst onderzochten wij de tot 1 januari 1998 gepubliceerde NHG-standaarden op aanbevelingen voor bloedonderzoek (beschreven in *Hoofdstuk 2*). Telkens als in een standaard bloedonderzoek werd genoemd, stelden wij de indicatie vast voor het verrichten van het bloedonderzoek en bepaalden welke tests in het kader van die indicatie geadviseerd werden. In 27 van de 64 onderzochte standaarden kwamen adviezen over bloedonderzoek voor. In 3 van deze 27 standaarden werd nadrukkelijk afgeraden bloedonderzoek te verrichten. In 5 gevallen was sprake van een onvolledige beschrijving van de indicatie voor in die standaard genoemde testen. Bij 23 van de 27 standaarden konden wij de indicaties voor bloedonderzoek en de bijbehorende testprotocollen vaststellen. Wij onderscheidden daarbij 5 categorieën voor het aanvragen van bloedonderzoek: aantonen of uitsluiten van een werkhypothese, vaststellen van onderliggende pathologie, volgen van het ziektebeloop, identificeren van therapiebeïnvloedende factoren en het monitoren van bijwerkingen van medicijngebruik.

Alhoewel enkele aanbevelingen voor bloedonderzoek onvolledig waren en soms voor vergelijkbare situaties lichte verschillen bestonden tussen verschillende standaarden, concludeerden wij dat de meeste standaarden per aanvraagindicatie duidelijke en eenduidige adviezen geven over de aan te vragen bepalingen in de vorm van een aanvraagprotocol.

Eisen waaraan een Aanvraagmodule moet voldoen.

Uitgaande van de in onze analyse van de NHG-standaarden gevonden indicatiegeoriënteerde aanvraagprotocollen ontwikkelden wij de laboratoriummodule BloedLink (beschreven in *Hoofdstuk 3*). Hierbij dienden wij een methode te kiezen waarmee wij het aanvraaggedrag wilden beïnvloeden. Wij kozen voor een vergelijkende studie tussen de methode die gebruik maakt van het aanvraagformulier met 15 voor de huisartsenpraktijk relevante bepalingen (methode Zaat) en de methode die gebruik maakt van een probleemgeoriënteerd aanvraagformulier (methode van Gend, van Geldrop en

Smithuis). Om de invloed van deze twee methoden op het aanvraaggedrag van huisartsen met elkaar te kunnen vergelijken, ontwikkelden wij twee versies van de laboratoriummodule BloedLink. De eerste versie, BloedLink-Beperkt, gaat uit van een beperkt aantal op het elektronisch aanvraagformulier getoonde bepalingen. In de tweede versie, BloedLink-Probleem zijn de laboratoriumprotocollen van de NHG-standaarden per aanvraagindicatie gerangschikt. Voor het overige bestond er geen verschil in functionaliteit tussen de beide versies van BloedLink. Beide versies werden met een identieke opmaak geïntegreerd met het elektronisch medisch dossier (EMD). In beide versies konden de huisartsen op dezelfde manier bepalingen toevoegen aan of verwijderen van het elektronische aanvraagformulier. Met gebruik van de laboratoriummodule kon in beide gevallen een aanvraagformulier worden geprint waarop de laboratoriumcode van de bepalingen, de gegevens van de patiënt en de gegevens van de aanvrager werden vermeld. Beide modules registreerden de aangevraagde bepalingen in het EMD. Door de twee versies van BloedLink te implementeren, waren wij in staat het verschil in effect van beide methoden op het aanvraaggedrag van huisartsen te onderzoeken.

De Invloed van BloedLink op het Aanvraaggedrag van Huisartsen

Ter vergelijking van het effect van de BloedLink-Probleem en BloedLink-Beperkt op het aanvraaggedrag van huisartsen werd, na stratificatie naar solopraktijken en groepspraktijken, een gerandomiseerd onderzoek uitgevoerd in 44 praktijken in de Delftse regio, waarin 60 huisartsen praktiseerden (beschreven in *Hoofdstuk 4*). De interventie vond plaats vanaf maart 1996 tot en met februari 1997. De primaire effectmaat was het gemiddeld aantal aangevraagde bepalingen per aanvraagformulier per praktijk tijdens de interventie. Na vergelijking van de interventieperiode met de twee voorafgaande jaren bleek in beide groepen het gemiddeld aantal aanvragen per aanvraagformulier duidelijk te zijn afgenomen. In de groep die gebruik maakte van BloedLink-Beperkt was sprake van een afname van 12% ($p=0.001$). In de groep die gebruik maakte van BloedLink-Probleem was sprake van een afname van 29% ($p<0.001$). In deze groep werd gemiddeld 20% minder

bepalingen aangevraagd (5.5 versus 6.9 bepalingen; Mann-Whitney test p=0.003, N=44).

Op grond hiervan kwamen wij tot de conclusie dat beslissingondersteuning met behulp van een laboratoriummodule gebaseerd op de NHG-standaarden een groter effect heeft op het aanvraaggedrag van huisartsen dan het aanvragen van bloedonderzoek met behulp van een beperkt elektronisch aanvraagformulier. Tevens concludeerden wij dat met behulp van beslissingondersteunende aanvraagmodules standaarden op een effectieve manier in de huisartsenpraktijk geïntroduceerd kunnen worden. Gezien de geringe inspanning die nodig was voor de introductie van BloedLink in de dagelijkse praktijk menen wij dat de door ons gevonden veranderingen in het aanvraaggedrag van huisartsen ook van toepassing zou kunnen zijn in andere praktijken die gebruik maken van een electronisch medisch dossier.

Protocoladherentie

Hoewel er een uitgesproken effect van BloedLink-Probleem op het aanvraaggedrag van huisartsen werd vastgesteld, kan een reductie van het aantal aangevraagde bepalingen niet zonder meer gelijkgesteld worden aan protocoladherentie. Daarom bestudeerden wij de mate waarin huisartsen de adviezen voor bloedonderzoek uit de NHG-standaarden ook daadwerkelijk opvolgden (beschreven in *Hoofdstuk5*). Wij definieerden protocoladherentie als het percentage aanvraagformulieren per praktijk dat overeenkwam met de adviezen voor bloedonderzoek uit de NHG-standaarden. Hierbij beoordeelden wij de aanvraagformulieren uit dezelfde onderzoeksperiode als beschreven in *Hoofdstuk 4*. Om vast te stellen of het afwijken van de aanvraagprotocollen gerelateerd was aan op handen zijnde herziening van de standaarden, onderzochten wij tevens welke standaarden herzien waren na de interventie periode. Wij vergeleken daartoe de drie meest frequent toegevoegde bepalingen van de aanvraagformulieren die de protocollen niet volgden met de adviezen voor bloedonderzoek in de herziene standaarden. In 39% van de probleemgeoriënteerde aanvraagformulieren bleek het geadviseerde protocol van de NHG-standaarden gevolgd te worden. Vergeleken met het

aanvraagprotocol werden bepalingen bijna nooit verwijderd van het aanvraagformulier, maar vrijwel uitsluitend toegevoegd. Opvallend was de bevinding dat de door de huisarts toegevoegde bepalingen, die er voor zorgden dat het aanvraagformulier het protocol niet volgde, wel voorkwamen in het aanvraagprotocol van de na de interventie-periode herziene standaarden. Deze bevinding bracht ons tot de conclusie dat huisartsen de adviezen voor bloedonderzoek uit de NHG-standaarden beschouwen als de basisnorm voor het aanvragen van bloedonderzoek. Tegelijkertijd echter anticiperen zij bij het aanvragen van bloedonderzoek op aanstaande herzieningen van de NHG-standaarden. De resultaten van onze studie zouden het gebruik van electronische medische dossiers voor het vastleggen van patiëntgegevens kunnen bevorderen.

Discussie

Wij concluderen dat *(beschreven in Hoofdstuk 6)* de standaarden van het Nederlands Huisartsen Genootschap (NHG) op het niveau van indicaties concrete en specifieke aanbevelingen bevatten voor het verrichten van bloedonderzoek. Op basis daarvan ontwikkelden wij een laboratoriummodule, die de huisarts beslissingondersteuning geeft bij het verrichten van bloedonderzoek. Door de huisarts de indicatie te laten bepalen voor het verrichten van bloedonderzoek beperkten wij de rol van de beslissingondersteunende module tot het genereren van testprotocollen behorend bij de door de huisarts gekozen indicatie. Het verrichten van bloedonderzoek op basis van de NHG-standaarden geeft een sterkere reductie van het aantal aangevraagde bepalingen dan het aanvragen van bloedonderzoek met behulp van een tot 15 voor de huisartsenpraktijk relevante bepalingen beperkt aanvraagformulier. Door het gebruik van de laboratorium-module BloedLink worden de NHG-standaarden ook daadwerkelijk toegepast tijdens het spreekuur. Huisartsen gebruiken de aanbevelingen voor bloedonderzoek uit de NHG-standaarden als uitgangspunt voor het aanvragen van bloedonderzoek. Door in te spelen op bevindingen uit recente literatuur lopen zij vooruit op de standaarden, waardoor hun "protocoladherentie" afneemt. Dit maakt een heroverweging van de wijze waarop en de snelheid waarmee de NHG-standaarden geactualiseerd worden noodzakelijk.

Curriculum Vitae

Marcus Antonius Maria van Wijk was born on august 27th, 1952 in The Hague, The Netherlands. He received his undergraduate education at the Gymnasium Sint Jans College in The Hague from 1964 until 1970. In that same year he started Chemistry studies at Leiden University. In 1971 he switched to Medical studies at the same university and graduated in 1978. He completed the vocational training for general practitioner in 1980. After one year occupational medicine he works as a general practitioner in Delft, the same region were the project that resulted in this thesis was performed. From 1990 through 1999 he was a staff member of the diagnostic centre of the Reinier de Graaf Gasthuis involved in continuing medical education on diagnostic testing. In 1994 he participated in the working group preparing the guideline for blood testing of the Dutch College of General Practitioners. From 1995 through 1997 he coordinated the working group on continuing medical education for general practitioners (WDH) in the Delft region. Since January 1999 he is part of the scientific staff of the department of Medical Informatics of the Erasmus University Rotterdam. In his spare time he loves playing the drums. He is married to Anneke Zomers and they live in Delft with their five children: Bart, Annemieke, Marlies, Eric and Frank.

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Het voltooien van een proefschrift is bij uitstek een verrichting die slechts met behulp van de inspanning van anderen door de promovendus tot een goed einde gebracht kan worden.

Door mij een aanstelling te bezorgen als coördinator van de huisartsennascholing op het gebied van laboratoriumonderzoek bij het toenmalige diagnostisch centrum SSDZ te Delft, heeft Ferry van Elven de eerste aanzet gegeven tot het schrijven van dit proefschrift. Zijn geesteskind "ELBOS" was de kiem voor BloedLink. Al in 1990 begon hij mij te overtuigen van de noodzaak van een in een huisartsen informatie systeem geïntegreerde laboratoriumaanvraag module.

Professor Jan van Bemmel heeft mij de gelegenheid gegeven dit promotie-onderzoek te starten. Zijn: "Marc ben je al beroemd?" beschouwde ik als een stimulans om niet te schromen mijn artikelen aan gerenommeerde tijdschriften aan te bieden. Jan, ik ben nog steeds niet beroemd, maar het proefschrift is wel af.

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Het engelengeduld van mijn kamergenoot Albert Vlug, bij het voor de zoveelste keer uitleggen van de verschillende applicaties op mijn laptop, getuigt eveneens van grote consideratie met mij als "nitwit"-informaticus. Zijn filosofische en humoristische commentaren op mijn stellingen echoën nog na.

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een tijd van vele bezuinigingen, zo lang mogelijk heeft laten bestaan waardeer ik zeer.

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Marc

Participating General Practitioners

The following general practitioners participated in the BloodLink intervention:

J.M. Baks, R.D.W. van Bentveld, Y.J. Bezuijen, J.P. Bijl, P. de Blooy, C.M.J. Bonekamp, G.O. Boonstra, H. Breedveldt Boer, J. Breugem, J.A. Brienen, P.J.A. Bucx, H.B.F. Derksen, W. van Donselaar, E. Driever, R.H. Dupuis, P. van der Endt, J.A.J. Garretsen, R. Glotzbach, R.J. de Haan, H. Harmans, T.M. van der Hoek, M Human-Breedveld, C. Jansen, C.H.F. Jonker, M. Jonquiere, P.E. Kalsbeek, W. Kamermans, L.E.M. Kleipool, A.M.A. van der Knaap, S.J. Kool, M.I.Th. Koopmans, P.C.J.M. Kop, E.H.M. Lange, S. Laverman, S.J. Lindenhout, M. Luitse, D. Maring, S. van der Meer, P.J.Th.M. Meijs, J.E.G. Nieuwkamer, J.B.M. Nijkamp, J. Oosthoek, M.A. Plasmans, L. Redel, A.R.N. van Rijckevorsel, F.J.N. Rijkee, W.F. Sandhövel, P.P.M. Schijen, F. Schreuder, H.S. Spijker, M. Steentjes, R. van Stijn, E.P.L.A. Timmermans, F.C.M. Touw, P.S.W. Verheyden, P.D. Visser, H.W. Visser, H.J.P. Vos, C. van der Weg, W. Wierema.