Sheffield Hallam University
School of Computing
and Management Sciences

INTEGRATION OF ALL INFORMATION SUPPORT SYSTEMS IN THE CLINICAL ENVIRONMENT

Sheffield Hallam University in collaboration with Central Sheffield Universities Hospitals Trust

Susana Carla de Oliveira Gonçalves

MPhil - July 1999

(Masters Degree in partial fulfilment with the requirements of the Sheffield Hallam University)

INTEGRATION OF ALL INFORMATION SUPPORT SYSTEMS IN THE CLINICAL ENVIRONMENT

II. ABSTRACT

Evidence based medicine (EBM) is an approach to patient care which ensures that potential advances in health care must be tested and proven to do more good than harm before they are incorporated into medical practice. It promotes the collection, interpretation and integration of patient reported, clinician observed and research-derived evidence. For this information to be used as an integral part of medical practice, regularly updated systematic reviews such as those organised through the Cochrane Collaboration are essential. It has been argued that electronic access to information sources from the health care professional's normal work place is the only feasible way to bring EBM into routine clinical practice where it is used as a framework for determining the care of individual patients.

Within the context of clinical decision-making using EBM, two sources of information are necessary. Firstly patient information, which includes treatment regimes, clinical assessments and the results of laboratory tests on a particular patient. Secondly reference information, which is the evidence base on which to justify the care delivered to that patient. It is believed that bringing patient and reference data together so that they can be accessed through a single workstation within the hospital workplace could provide an effective tool to support healthcare delivery using EBM. The concept of the clinical workstation is one that has been used to describe a single workstation which gives access to all clinical information. If this concept is applied to a workstation to support EBM, then both patient specific and reference information must be available through the workstation.

This study describes work at the Royal Hallamshire Hospital (RHH) in Sheffield, an acute 850-bedded teaching hospital located in an industrial city. The work aims at integrating access to reference and patient data through a single user interface – a Web browser – as a method of providing direct support for the delivery of EBM. A user-centred iterative approach to the research has been employed and in this study the user requirements and a prototype workstation to support evidence based medicine are described and evaluated.

IV. ACKNOWLEDGEMENTS

Firstly I am most thankful to Bob Steele, Adrian Wilson and Chris Franks for all of the continuous advice, support, enthusiasm, backing as well as friendship.

I would like to thank all medical staff and other clinicians from the Royal Halllamshire Hospital for their co-operation and feedback, especially those that participated directly into to the study.

I would also like to thank the staff from the IT department of the Royal Hallamshire Hospital where I have been working during this study.

Finally I am extremely grateful to Nuno for all his belief, enthusiasm and constant encouragement.

INTEGRATION OF ALL INFORMATION SUPPORT SYSTEMS IN THE CLINICAL ENVIRONMENT

I. COVER 1

II. ABSTRACT 2

III. DEDICATION 3

IV. ACKNOWLEDGEMENTS 4

V. SYNOPSIS 10

PART I – INTRODUCTION AND THE CLINICAL SETTINGS

1. BACKGROUND 12

1.1 Introduction – I.T. and hospitals 12

1.2 Computer Supported Collaborative Work and Groupware 17

1.3 Clinical Decision Making 18

1.4 Evidence Based Medicine 18

1.5 Electronic Patient Record 19

1.6 Information Support Services 20

1.7 Clinical Support Systems 21

2. THE CLINICAL ENVIRONMENT 22

2.1 Description of the working environment 23

2.2 Results Reporting System 23

2.3 Use of the Results Reporting System in the clinical environment 25

2.3.1 Results Reporting System and information security 26

2.4 Problems of I.T. in the clinical environment 28

2.5 Clinical decision support systems 29

2.6 Information requirements in the clinical environment 30

3. I.T. SYSTEMS IN THE CLINICAL ENVIRONMENT 31
3.1 Information support services 31
3.1.1 Medical databases 31
3.1.2 Medline 31
3.1.3 Cochrane Library 32
3.1.4 Differences between Cochrane Library and Medline 33
3.1.5 Organised Medical Network Information 34
3.1.6 BIDS 34
3.1.7 Cliniweb 35
3.2 Clinical support systems 35
3.2.1 Patient Administration System (PAS) 35
3.2.2 Results Reporting System (RRS) 37
3.2.3 Pharmacy and I.T. 37
3.2.4 Laboratories and I.T. 37
3.2.5 Protocols of Care 38

4. DEVELOPMENT OF THE WEB 39
4.1 The Internet 39
4.1.1 How does the Internet work? 39
4.1.2 What is an Intranet? 40
4.2 Use of Internets and Intranets in medicine 41
4.3 Problems with the use of the Internet and Intranets in medicine 42
4.4 Merits of migrating to a Web interface 43

5. THE WEB AND INFORMATION SYSTEMS 45
5.1 Search Engines 45
5.1.1 How does a Search Engine Work? 45
5.1.2 Subject catalogues or Medical Search Engines on the Internet 46
5.2 Information services on the Internet 48
5.3 Information quality on the Internet 49
5.3.1 Information quality 49

5.3.2 Peer Review evaluation and the Internet 50
5.4 Information searching on the Internet 51
5.5 Intelligent Search Engines 51

6. SOFTWARE DEVELOPMENT, METHODOLOGY AND TECHNIQUES 53
6.1 Methodologies and techniques – an overview 53
6.2 User centred approach and iterative design 54

PART II – BUILDING AND EVALUATING A CLINICAL WORKSTATION PROTOTYPE

7. INTRODUCTION TO THE DEVELOPMENT OF A CLINICAL WORKSTATION TO SUPPORT EVIDENCE BASED MEDICINE 59
7.1 Use of the Web interface in the Results Reporting System 59
7.2 Use of the Web interface in information services 60
7.3 Evidence Based Medicine and the Web 61
7.4 Integration of Web based services with clinical tasks 61
7.5 The need for a consistent interface 62

8. PLANNING HOW TO GATHER DATA FOR ANALYSIS, SPECIFICATION OF REQUIREMENTS AND FORMS OF EVALUATION 64
8.1 Where to find evidence 64
8.2 Methods of gathering data 66
8.2.1 Interviews 66
8.2.2 Different types of interviews 67
8.2.3 Questionnaires 67
8.3 Overview of interviews and questionnaires applied 68
8.3.1 Objectives of the semi-structured interviews 69
8.3.2 Plan of semi-structured interview design 70
8.3.3 Plan of evaluation questionnaire design 71

8.3.4 Objectives of the evaluation questionnaire 72
8.3.5 Evaluation by observation of the Clinical Workstation in the workplace 73
8.4 Problems encountered during planning the interviews and design of questionnaires ..73
8.5 Conclusions on selected methods for the requirements and evaluation of the Clinical Workstation 75

9. DETERMINING THE USER REQUIREMENTS 76
9.1 Method of determining the user requirements 76
9.2 Semi-Structured interview design 77
9.3 Obtaining the user requirements 77
9.4 Identified user requirements 79

10. INFORMATION QUALITY AND THE MEDICAL STAFF 81

11. DEVELOPMENT OF A PROTOTYPE CLINICAL WORKSTATION 83
11.1 A prototype Clinical Workstation 83
11.2 Method applied for the development prototype of the clinical workstation 84

12. EVALUATION OF THE PROTOTYPE CLINICAL WORKSTATION 89
12.1 Discussion of the results 90
12.2 Conclusions on evaluation 91
12.3 Further development cycles 93

PART III – CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

13. CONCLUSIONS 95
13.1 Summary of Conclusions 96
13.2 The future 96
13.3 An effective approach to training clinicians 97

14. FURTHER WORK – GUIDELINES FOR OTHERS AND RECOMMENDATIONS 99

14.1 Use of this technology in further applications in the wards: towards an Electronic Patient Record 100

14.2 Suggested improvements to the Clinical Workstation 101

15. REFERENCES 102

16. APPENDIX A – Screen shots from the Results Reporting System 105

17. APPENDIX B – Screen shots from the Clinical Workstation 117

18. APPENDIX C – User requirements questionnaire from structured interview 130

19. APPENDIX D – Evaluation questionnaire 134

20. APPENDIX E – Paper presented at SHIMR99 138

V. SYNOPSIS

This thesis is divided into 3 main parts:

Part I: *Introduction and the clinical settings.*

Part II: *Building and evaluating a Clinical Workstation prototype*

Part III: *Conclusions and suggestions for further work.*

Part I includes an overview of hospitals and their I.T. requirements as well as the clinical environment and its suitability for a web based information system. In addition it looks at some of the methodologies and techniques used to assist in the development and management of software.

Part II starts by looking at the development and use of a Web based interface, methods of gathering data from users and determination of user requirements for the Clinical Workstation. It also describes the development and evaluation of the prototype Clinical Workstation to support Evidence Based Medicine.

Part III includes conclusions of the work completed and some guidelines and recommendations for further work in the medical field.

All appendices appear at the end of this thesis.

PART I

INTRODUCTION AND THE CLINICAL SETTINGS

1. BACKGROUND

Medical informatics, according to Shortliffe et al [1] is:

" ...the rapidly developing scientific field that deals with the storage, retrieval, and optimal use of biomedical information, data, and knowledge for problem solving and decision making."

1.1 INTRODUCTION – I.T. AND HOSPITALS

Since 1879, health professionals have had access to bibliographic tools that can be used to identify published research. Various databases now available in an electronic form are able to retrieve medical information in a quick and efficient way. According to Kiley [2], the first database to emerge was Index Medicus. This database was later joined by others including Excerpta Medica and Psychological Abstracts. Recently, it has become possible to access peer reviews of groups of articles, providing systematic reviews such as those from Cochrane Collaboration Database and the NHS Centre for reviews and dissemination (NHSCRD). So a physician looking for recent reviews is able to easily find highly relevant key publications.

Electronic storage and access to medical data is becoming increasingly common. Advances in computer technology have made it possible to store vast amounts of information in databases and transmit or receive this information rapidly to and from anywhere in the globe. At the heart of this technology is the Internet, a world wide computer network that links together over 10 million computers in more than 80 countries [3]. The Internet promises enormous benefits for medical education, research and clinical practice. It can also constitute a tool to support and facilitate group working.

Collaborative working is essential for effective patient care in a hospital ward environment. As Grudin [4] describes, recent technological developments have encouraged the appearance of Computer Supported Co-operative Work (CSCW). Examples of these developments are: inexpensive computer systems which provide access for all members of a group; technological infrastructures which support communication and co-ordination (e.g. networks and associated software); increased familiarity with computers leading to the use of more software; developers seeking new ways to enhance and differentiate their products. CSCW enables software known as Groupware to allow professionals, including health care professionals, to work co-operatively without concern for their physical location. Ellis, Gibbs and Rein [5] suggest that Groupware systems are computer based applications that support groups of people with common tasks and provide an interface to a shared environment.

In a hospital environment, most patient care activities occur in the context of workgroups. Thus there is a demand to assist such workgroups in communicating, collaborating and co-ordinating their activities. This is the goal of Groupware.

Clinical staff working in a ward environment continually need to obtain or send information in order to treat patients effectively. For example:

- Information needed to assist in the clinical decision making process, e.g. The results of laboratory investigations and the results of clinical examinations, etc;

- Information requests, e.g. when tests are ordered;

- Information to support the clinical learning process of medical staff.

For the past few years, hospitals have been trying to acquire or develop computer systems to hold patient data. These systems aim to improve patient treatment delivery.

"For many years the medical community and I.T. suppliers have sought to improve, refine, and extend the support that computer based systems offer in the delivery and administration of health care" - Scott Wallace [6].

Understandably, patient data has always been a focus of this effort. In the Royal Hallamshire Hospital (RHH), development effort has gone into providing systems that support patient care including the RRS (Results Reporting System). This is one of the systems containing patient data available in the ward environment. It is widely used by medical staff and is mainly designed to enable clinical staff to send clinical laboratory test requests and receive laboratory test results. The computerised Results Reporting System (RRS) has considerably reduced the delay before clinicians have access to test results. The system holds important clinical data that can be consulted at any time, day or night, by clinicians. It helps the clinical group of users to accomplish their daily tasks more effectively.

May [7] identifies the importance of decision making in patient care and classifies decisions from familiar to unfamiliar and from standardised to open. He considers *standard and familiar* decisions e.g. the ones with readily recognised patterns that have been experienced many times before and can be considered almost automatic. *Open and familiar* decisions are characterised by individual parameters for which the decision-maker might not have a method or approach instantly available. *Standard but unfamiliar* decisions come across with an appropriate well-documented response. *Open and unfamiliar* decisions usually do not have much structure. They are usually made slowly with a careful consideration of all elements.

Clinical staff normally require very quick response for results of laboratory tests as well as requiring quick retrieval of relevant data for supporting the best clinical care and decision making. Their clinical decisions are influenced by diverse factors. However they are mostly based on the patient data they access and on the reference data that they search for. On the basis of this patient and reference data they are able to justify their decisions, whether they are standard, familiar or unfamiliar. Because they frequently have patients

in more than one location, clinical staff move from room to room and floor to floor around the hospital. All the wards in the RHH have a terminal for the RRS system. Since there is already a hospital wide network which provides clinical information to the various departments, it seems appropriate to take the next step in the direction of creating access to non-patient specific information (reference information) through the same network workstations.

Medicine cannot be efficiently practised without doctors having access to large amounts of information and patient care delivery is affected by the quality of the data accessed by medical professionals. Before making a diagnosis or any other medical decision, they extract patient and reference data from the various sources available. These include the RRS, hospital guidelines, the BNF (British National Formulary), the hospital library and the opinions of their colleagues. The use of the hospital protocols or guidelines has increased substantially, mainly as a result of medico-legal pressures. The hospital protocols, produced by different departments are used by medical staff when both planning and delivering treatment to their patients.

The use of reference information includes searches from library books, equipment manuals, national standards (e.g American Association of Anesthesia) and local standards. The implications of these searches and their results in the day to day diagnosis and treatment of patients, is very important. A number of studies have assessed the effect of Evidence Based Medicine on clinical decision making, including one by Wood and Wright [8] using data from a Canadian study. In this study the decisions made by general medical practitioners in the Trent Health Region were analysed. The results showed that patient management was altered in two-thirds of the cases when reference information was incorporated into the clinical decision making process. A selected group of participants were asked to state the last time they needed to seek information to assist in the decision-making process and to give details of a patient problem presented together with the specific types of information sought. The sources of information available were generally considered relevant, accurate and current. In about two-thirds of cases, the information obtained changed the way the situation was handled. In about one-third of

the cases, the information obtained changed the choice of drugs, avoided additional tests on a patient, changed the advice given to the patient and avoided referral or admission to hospital.

Giving medical staff the opportunity of accessing large amounts of information quickly, allows them to use it to justify treatment delivery and to increase their knowledge in that particular medical field. It would be very convenient for relevant data to be available on the ward terminals from within a consistent interface. It would also give clinicians the correct environment to apply evidence based medicine treatment to their patients on the wards.

Nowadays use of the Internet is increasing substantially. The Internet is cited everywhere - in the newspapers, television and advertisements. Being so publicised and talked about, it logically leads to a growing interest among health professionals. The Internet has the potential to be widely used to support clinical decision making. A large quantity of data can be found online on the Internet. This data is constantly updated and contains information about clinical problems, the appropriate care procedures and their benefits and limitations. In addition, information about medical and institutional resources is also available.

However, many Internet users find the Web frustrating, experiencing difficulties in achieving effective search results. Intranets can avoid these problems by restricting the search to the data available within an organisation. Both Internets and Intranets provide a way of integrating information from different sources and different types with a single set of tools. Intranets apply technologies developed on the Internet, especially World Wide Web software, to an organisation's private network. They provide text, graphics, video and audio availability, widely and quickly (faster than modem based communications), and enable different users to be involved in usability tests, comment on the work in progress, links to work team materials and also protect confidentiality. Intranets provide effective communication.

To date, much of the emphasis on hospital information systems, has been on putting the infrastructure in place. This includes hospital wide networks, basic patient information systems and administration systems. The majority of this infrastructure only indirectly provides support for patient care.

The next stage is the evolution of information support systems to provide support for the routine care of patients. The current focus is on Evidence Based Medicine where the choice of patient treatment must be justified from published information. This thesis describes the development of a prototype clinical workstation to support Evidence Based Medicine which integrates reference and patient information.

1.2 COMPUTER SUPPORTED COLLABORATIVE WORK AND GROUPWARE

Nowadays, the way that working activities occur around the hospital environment encourages the use of Computer Supported Collaborative Work (CSCW). The most important contributory factors to the use of CSCW around hospitals can be considered to be the increased familiarity with computers amongst the clinicians, which leads to an incentive to use more software. Also, falling costs of technology makes it much more available in general, and so speeds development of the technological infrastructures to support communication and co-ordination [4].

CSCW enables software, known as Groupware, to allow clinicians to work in the group context without concern for their physical location. As most people's working activities occur in a group context, there is a great demand to assist groups in communicating, collaborating and co-ordinating their activities. Groupware systems are computer based systems which support groups of people with common tasks and which also provide an interface to a shared environment. Groupware is designed to support and facilitate the group's work.

1.3 CLINICAL DECISION MAKING

The delivery of care to individual patients in acute hospitals essentially involves repeated cycles of health care professionals assessing the physical, physiological and biochemical state of the patient and then using their professional knowledge and judgement to plan the care of that patient. This process may be broadly defined as 'clinical decision making'. A key element of the clinical decision making process is the collection and processing of data. These activities have traditionally been centred on paper records. Computer programs designed to collect and process patient data can support health care professionals in their clinical decision making and such systems are commonly referred to as Clinical Decision Support (CDS) systems [9] (section 2.5).

If clinical decision making is to be carried out within an Evidence Based Medicine framework, then health care professionals not only need access to patient specific data but also to reference data to support the decisions they make. A wide variety of reference materials are available including textbooks, journals, drug references and equipment manuals. Other, perhaps less obvious, sources of reference material include national, international and local protocols of care and safety regulations. A large quantity of such medical reference information can be found on the Internet - information which is being continuously extended and updated.

1.4 EVIDENCE BASED MEDICINE

Evidence based medicine (EBM) is an approach to patient care that promotes the collection, interpretation, and integration of patient-reported, clinician-observed and research derived evidence. It ensures that potential advances in health care must be tested and proven to do more good than harm before they are incorporated into medical practice [10]. The term EBM has been used not only to describe the use of evidence to support clinical decision making but also the reference resources themselves [11]. More properly the application of evidence to support clinical decision making should be referred to as

evidence based clinical practice. However this term is not commonly used. Therefore EBM will be used to refer to both evidence based clinical practice and the reference sources: the context in which it is used making the meaning clear. The best available evidence, moderated by patient circumstances and preferences, is applied to improve the quality of clinical decision making. "Critical Appraisal" of the medical literature was introduced as an approach to reading that would help practitioners filter clinically relevant and methodologically sound studies from the large number of articles appearing in medical journals [10].

EBM requires new skills from the clinicians, including efficient literature searching and the application of rules of evidence in evaluating the medical literature. Medical literature contains evidence that can be used to support patient care, but only a small portion of it describes significant advances in the cause, diagnosis, prevention, and treatment of disease. Cook, Mulrow and Haynes [12] suggest that systematic reviews can help health care professionals by summarising large amounts of evidence and explaining the differences between different studies on the same subjects. They provide interpretation and support the application research evidence. In a typical week a health care professional will treat patients with different conditions and will need to make many decisions. There are many factors affecting those decisions. Each health care professional possesses his or her own knowledge, experiences and values. Timely and useful evidence from the biomedical literature should form an important component of clinical decision making. If there is evidence that one treatment has proved to be better than another, health professionals need to be aware of this to be able to apply the appropriate treatment to patients at the right time.

1.5 ELECTRONIC PATIENT RECORD

"The electronic health record is a computer stored collection of health information about one person linked by a person identifier" [13].

The Electronic Patient Record (EPR) describes a record containing a patient's personal details - name, date of birth, hospital number - their diagnosis or condition and details about the treatment or assessments undertaken by a clinician. It is typically provided by one institution organised as an "episode of care" based on when a particular illness is treated [14].

Although most patient data is still kept on paper records, EPR systems are more likely to provide legible, accurate, safe, secure and available records which can be readily and rapidly retrieved and communicated. An EPR can better integrate the latest information about a patient's care from different departments in a hospital and can be accessed by the clinicians in different physical locations. It can also be more easily accessed for audit research and quality assurance purposes.

Thus, an EPR allows easy access to the updated patient data anytime it is needed by the clinicians. It is accessible 24 hours a day and it is also more secure, as its access is controlled by a logon procedure which ensures access by only those who have the right to do so. It is a very effective and quick way of accessing patient data, which enables better communication.

1.6 INFORMATION SUPPORT SERVICES

In the context of this work, information support systems are all services accessed by clinicians to increase their knowledge in the medical field. These are varied and include

books, printed journals, local and international protocols of care, medical dictionaries and medical database services (e.g. Medline[1]). Some information support systems promote or expose clinicians to EBM (e.g. Cochrane Library – section 3.1.3). These can also be classed as providing reference data.

1.7 CLINICAL SUPPORT SYSTEMS

Clinical support systems are all systems within a health care institution containing patient demographic and clinical data. They provide the clinicians with access to patient specific data and recorded clinical history. They provide the necessary information to identify patients and their associated clinical history. Clinical support systems provide the basic information about the patients.

[1] From the U.S. National Library of Medicine, the Medline database is widely recognised as the premier source for bibliographic and abstract coverage of biomedical literature.

2. THE CLINICAL ENVIRONMENT

In developing information systems it is essential to have an understanding of the environment in which they are going to be used. The Royal Hallamshire Hospital (RHH) is situated in Sheffield, UK and forms part of the Central Sheffield Universities Hospitals (CSUH) Trust. It is an acute 850-bedded acute teaching hospital in an industrial city, located in the same building as a medical school. The main activities concerning this project occur within the RHH and are based in the ward environment of this hospital.

INPATIENT FINISHED CONSULTANT EPISODES				
SITE	**InPatients**	**Day Case**	**OTHER**	**TOTAL**
CCDH	4	1479	230	1713
RHH	12521	22758	19341	54620
JHW	1475	3618	13624	18717
TOTAL	**14000**	**27855**	**33195**	**75050**

OUTPATIENT ATTENDANCES			
SITE	**NEW**	**Follow Up**	**TOTAL**
CCDH	22642	65096	87738
RHH	64942	202285	267227
JHW	10690	18335	29025
TOTAL	**98274**	**285716**	**383990**

Table I – Inpatient and outpatient attendance for the CSUH Trust 1998/99

Legend: CCDH - Charles Cliford Dental Hospital
RHH - Royal Hallamshire Hospital
JHW - Jessop Hospital for Women

The Trust includes Charles Clifford Dental Hospital (CCDH), Royal Hallamshire Hospital (RHH) and Jessop Hospital for Women (JHW) in Sheffield. Table I presents data collected by the Information Department of the RHH up to June 1999, showing inpatient and outpatient attendance figures for the period of 1998/1999.

2.1 DESCRIPTION OF THE WORK ENVIRONMENT

The RHH has around 35 wards and a constantly increasing number of out-patient clinics using the RRS system. A typical ward will have a varied number of rooms, with around 6 patient beds per room, a nurse's station and a doctor's office. The clinical staff present on the wards consist mainly of senior and junior medical staff, sisters/charge nurses, staff nurses and pharmacists. A significant part of a clinicians' work when assessing patients is centred around the nurse's station or the doctor's office. These locations are always busy and the main preparation for patient treatment takes place in this environment.

2.2 RESULTS REPORTING SYSTEM

To effectively accomplish their daily tasks, medical staff require a quick response on results of all tests they request from hospital laboratories. For many years a time delay on these transactions has been identified for both the medical staff and the several laboratories. An audit report carried out in 1994 by the laboratory of medicine in the RHH showed that some reports were delayed by more than a day. The importance of the data movement between laboratories and the patient data accuracy was the trigger for the development of a system to deliver clinical laboratory results to the wards via a hospital wide network. The process of obtaining results starts with the clinician completing a request form on the hospital ward, sending it with a blood sample to the laboratories, and waiting for the result to come back to the ward after the sample has been processed by the laboratory.

This system also allows the clinicians to print request forms automatically and keeps all old results history from 1995 up to the present. This system is called the Results Reporting System (RRS) and is currently available widely around the hospital.

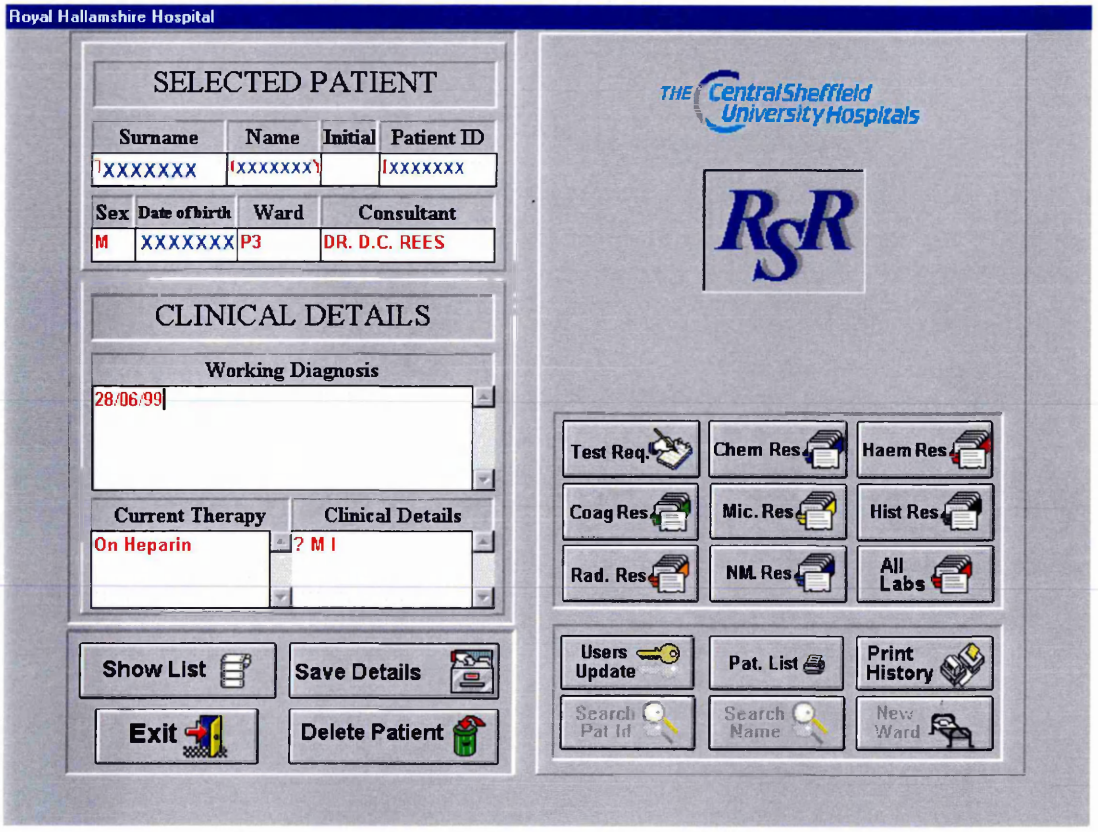

Fig. 1 - RRS system available on all the wards of the RHH wards

The RRS system (Fig. 1) holds patient specific data and laboratory results from Clinical Chemistry, Haematology, Coagulation, Microbiology, Radiology, Histopathology and Nuclear Medicine. It also prints out request forms for the different laboratories at a clinician's request.

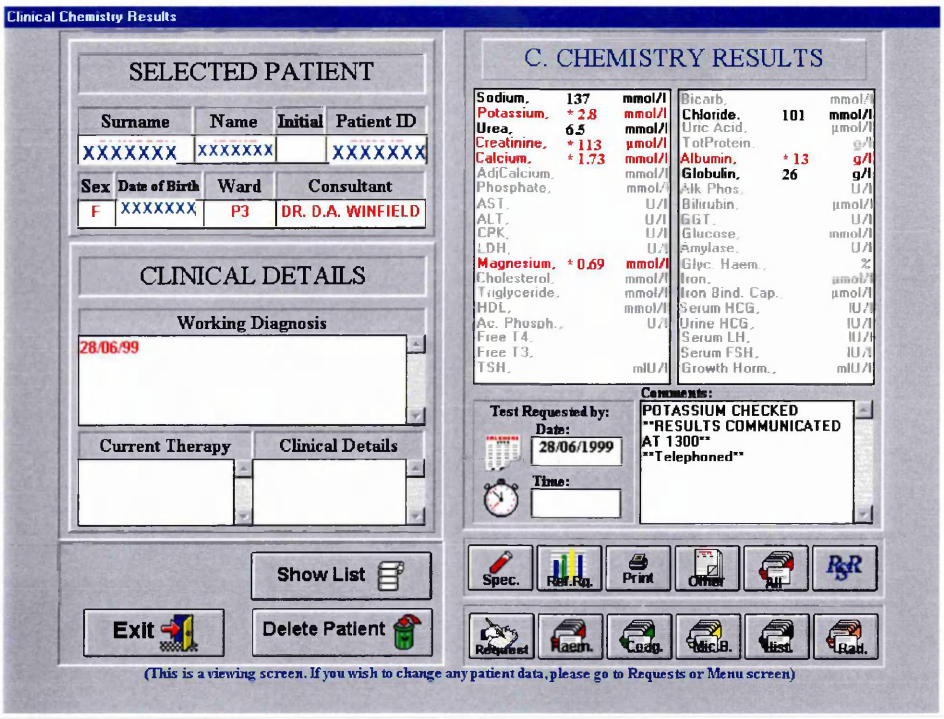

Fig. 2 - Test results from the laboratory of medicine on the RRS System.

Fig. 2 illustrates the results from the laboratory of medicine, available on the RRS system on the hospital wards. The system works with different levels of user access security and is available to all clinicians throughout the hospital. The clinicians include senior and junior medical staff, pharmacists and more recently, sisters, charge nurses, staff nurses, medical secretaries and some of the ward clerks.

2.3 USE OF THE RESULTS REPORTING SYSTEM IN THE CLINICAL ENVIRONMENT

At the RHH the RRS is one of the systems containing patient information developed to run in the ward environment. It is widely used by the clinical staff and is designed to enable staff to send clinical laboratory test requests and receive laboratory test results.

The RRS system on the wards is normally in one of the two locations which best serve the clinicians who need access to it: the nurse's station or the doctor's office. The machines running this system are permanently switched on and display the logon screen at all times, allowing easy access for whoever needs it next. This system provides the clinicians with extremely easy access to patient data 24 hours a day. The patient data held within the system is secure. It can only be accessed by users holding a unique password code. In case one of the users abandons the system without logging out, the system times out, going straight back to the logon screen ready for further use.

The system allows clinicians to enter details of the patient clinical details, working diagnosis and current therapy (Fig. 1). This supports collaborative working between the health care professionals (section 1.2).

The system is an important source of data to support the clinical decision making process and it therefore forms the focus for patient data in the work reported in this study.

2.3.1 Results Reporting System and information security

Up until recently computer security was relatively easy to implement. However, nowadays wide area networks and Internet access have made security more complex. The benefit of greater access to medical information increases the risk of violation of patient confidentiality. The RRS system provides the users with a logon screen (Fig. 3), which disallows unauthorised access to the system. All those who have access to the RRS system have to sign a confidentiality protection form. This helps clinicians to be aware of the importance of keeping security around patient data, which has always been an issue in hospital environments. It also holds the clinicians responsible for not giving their passwords to any other individual even if they work directly with them. The present system does however allow clinicians to access results or notes for patients that are not directly under their care.

User accounts are organised by ward and firm[2]. This provides the clinician with access to all their patients in that ward and also to some located on different wards (outliers[3]). It also gives clinicians access to patients under a different firm but who are on the same ward, to allow for cover when needed. Although it provides some degree of security, it is not the ideal situation for those patients who desire their records not to be accessed by anyone but their own doctor. However, it can be argued that clinicians on the wards will be able to access the patient notes if they need to, and passwords at least protect patients from unwanted access from non-users of the system. Note that any patient results coming from the Infectious Diseases department or needing to be kept secret for any other reason, are never identified by name but by a unique number which is related to that patient only. The clinicians will not be able to access confidential data unless they are authorised and possess that number.

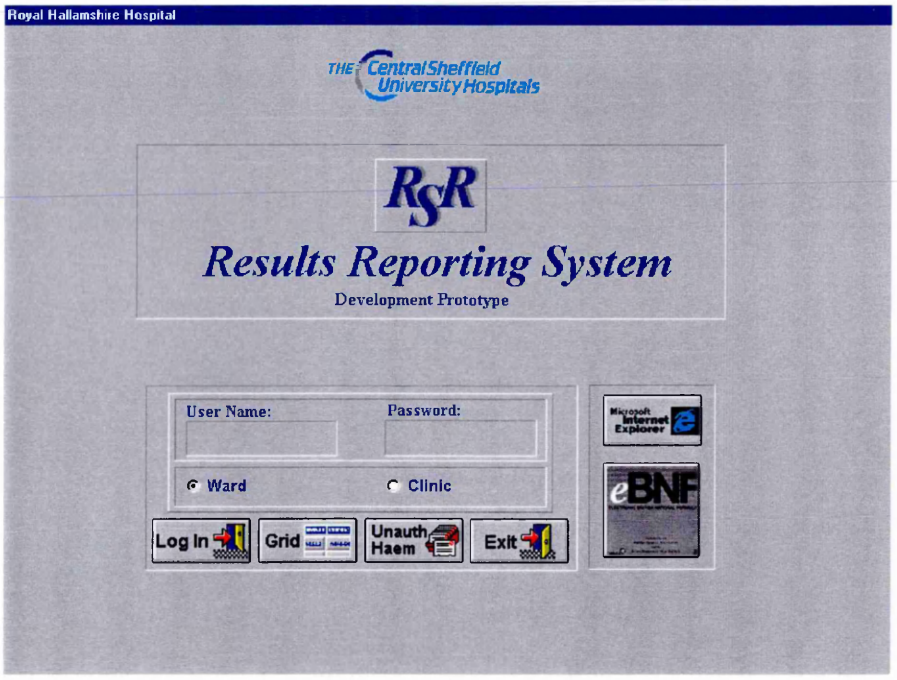

Fig. 3 - Logon screen, part of the RRS System available on the wards of the RHH.

[2] Firm is a team of doctors all working with the same consultant(s).
[3] Outliers are patients that belong to a firm but physically reside on a different ward. This can be due to various reasons including bed availability.

Fig. 3 represents the logon screen of the RRS System. It ensures security within the system, validating passwords for its users and automatically logging off forgetful users after a short period of time. It also gives access to other services that can be used by clinicians on the wards without requiring password validation. Some of these services are illustrated in Appendix A together with additional screen shots from the RRS system.

2.4 PROBLEMS OF I.T. IN THE CLINICAL ENVIRONMENT

The clinical settings of the RHH are part of a very busy environment with a population of varied clinical staff with critical tasks to achieve and patient treatment to pursue. The clinicians in such a busy environment should be allowed access to all the types of information which potentially improve patient assessment and treatment.

One of the problems for I.T. in the clinical settings is the user's lack of experience in using computer technology. An easy to use interface is essential and the time required for training the staff needs to be kept to the minimum. The clinicians are always very busy and are only too ready to give up on I.T., especially if this requires spending more than a few hours of their busy time learning how to use it.

The RRS system described previously in section 2.2 is a typical example of a system which, although it possesses a user-friendly interface, requires an extensive program of training to be delivered by the system's administrator. The training program is mainly based on one half-hour session training for each user, supported by a 16 out of 24-hour help line. It was rapidly understood that if the user was computer illiterate and for some reason missed this first session, they would avoid using the system as much as possible. This is thought to result from a fear of computer systems and needed to be overcome. Accordingly, a computer training process was planned and applied. Lack of training would lead users in to spending hours chasing results around the hospital. This would be through time on the telephone or physically going to all the different laboratories to get the results.

As the developer and system's administrator for the RRS system, the author rapidly understood that training would be the basis for future use of the system by a particular user. If this training program was not in place at the time the user was introduced to the system, the RRS would never become part of the everyday life of the clinicians, as the users were mainly inexperienced computer users.

The training program for this system is still in place as hospital staff rotation occurs twice a year, every year. The system is user friendly, but training is still relevant for the users. Having about 504 medical staff, 1905 nurses and 41 pharmacists[4] currently working in the hospital has resulted in a big ongoing task for those involved in the training program.

2.5 CLINICAL DECISION SUPPORT SYSTEMS

Some years ago, the use of computers by health professionals was not very common. The use of computers has been increasing steadily and nowadays people value the advantage computer technologies can offer to support their professional activities. Software has become easier to use and individuals have begun to lose their fear of using computers to support their work. Computers can hold huge amounts of data and can be consulted at any time. They can effectively support clinical decision making in relation to patient care.

"A medical-decision support system is any computer program designed to help health professionals make decisions", Shortliffe [9].

Decision support systems are an example of the software packages that can help clinicians with diagnosis and treatment. Having decision support systems available on the RHH wards would be highly advantageous. According to Shortliffe there are three types of decision support systems:

[4] Information gathered through the personnel department of the Royal Hallamshire Hospital.

1. *tools for information management* - such as systems that provide access to reference data needed for patient treatment decision making (e.g. Medline). They provide information but they don't help the user to apply that information to a particular decision task. In this study, information of this type is referred to as reference data.

2. *tools for focusing attention* - such as clinical laboratory systems that are designed to alert the physician to abnormal values, list possible explanations for abnormalities or alert for possible drug iterations (e.g. RRS system, already on the RHH wards). In this study, information of this type is referred to as patient data.

3. *tools for patient specific consultation* - they provide customised advice based on sets of patient specific data. The basic information to support such consultation is hospital departmental protocols.

2.6 INFORMATION REQUIREMENTS IN THE CLINICAL ENVIRONMENT

In order to apply treatment to patients and to be able to judge medical conditions within a formal EBM framework, clinicians need access to patient data as well as reference data. The key to practising EBM in a clinical environment is the seamless integration of reference and patient information and its presentation in a form which is readily and effortlessly accessible. EBM can only be part of a daily diagnosis and treatment when it is available at the bedside. It would be advantageous and very useful to be able to access both patient and reference information in a clinical environment, which in the RHH would be the wards. Information should be available on the wards so that clinicians can effectively access it to help them with delivery of care.

3. I.T. SYSTEMS IN THE CLINICAL ENVIRONMENT

The key element of an EBM workstation is the integration of reference and patient information. This section examines I.T. systems available to support clinical decision making. Nowadays, the availability of medical databases in machine-readable form, means that they can be considered for use in the clinical environment. This section looks at some of the data available for users to access in a traditional paper based way and also data which is becoming available electronically.

3.1 INFORMATION SUPPORT SERVICES

Reference data to support clinical decision making comes in the form of medical books, specialist magazines, protocols and medical databases. Reference data is data about clinical conditions, investigation strategies and treatment options, as opposed to data about specific patients. When in machine-readable form these sources of data are normally available in two different forms: CD ROMs in libraries or databases for access through the Internet.

3.1.1 Medical Databases

Medical databases are databases of articles and citations in the field of medicine. Very recently there has been an increase in the availability of a range of Internet versions of commercial and academic online databases.

3.1.2 Medline

Medline, produced by the US National Library of Medicine, is one of the most popular database services used to identify references in the published research literature. After

comments from clinicians[5] it was rapidly realised that the name Medline automatically offered credibility to this service. It provides a tool for applying EBM to the clinicians' different needs.

Access to Medline is currently available through a different number of routes, including local network services or the Internet. A varied number of Internet sites provide a range of the free Medline services, but they contain references only, as opposed to full articles. Also, individual registration is often required. Some of the subscription Medline services available (e.g. OVID[6]) provide on the spot access to the full article for some of its references.

3.1.3 Cochrane Library

The Cochrane Library is a collection of reference databases that hold high quality information to help guide clinical decision making, promoting EBM to the users. It is an electronic publication designed to supply high quality evidence to inform people providing and receiving care as well as those responsible for research, teaching, funding and administration at all levels [15].

The data availability on the Cochrane Library is regularly updated and reviewed in relation to the effects of healthcare interventions. The Cochrane Library includes:

- *The Cochrane Database of Systematic Reviews (CDSR)* -This is a collection of regularly updated, systematic reviews of the effects of health care, maintained by contributors to the Cochrane Collaboration. New reviews are added with each issue of the Cochrane Library. Evidence is included or excluded on the basis of explicit quality criteria to minimise bias.

[5] Clinicians are those directly involved in the care and treatment of patients, including doctors, dentists, nurses, midwives, health visitors, pharmacists, opticians, orthoptists, chiropodists, radiographers, physiotherapists, dieticians, occupational therapists, medical laboratory scientific officers, orthotists and prosthetists, therapists, speech and language therapists, and all other healthcare professionals.

[6] The Chest OVID biomedical service comprises a collection of datasets including Medline, CINAHL, CancerLit, and six Ovid BioMedical Journal Collections.

- *Database of Abstracts of Reviews of Effectiveness (DARE)* –This includes structured abstracts of systematic reviews from around the world which have been critically appraised by reviewers at the NHS Centre for Reviews and Dissemination at the University of York, England. DARE also contains references to other reviews which may be useful for background information.

- *The Cochrane Controlled Trials Register* -This is a bibliography of controlled trials identified by contributors to the Cochrane Collaboration and others, as part of an international effort to hand search the world's journals and create an unbiased source of data for systematic reviews. CCTR includes reports published in conference proceedings and from many other sources not currently listed in Medline or other bibliographic databases.

The Cochrane Library covers all areas of healthcare, although at present there are more reviews available in some areas than others.

3.1.4 Differences between Cochrane Library and Medline

The Cochrane Library and Medline both hold high quality information to help guide clinical decision making and to promote, collect and distribute reference information to clinical professionals. Although they are similar they are not identical.

The Cochrane Library additionally includes [15]:

- Full text, including graphs, of the original systematic reviews produced by the Cochrane Collaboration.
- Reviews which are regularly updated as new information becomes available and in response to comments and criticisms.
- Critical appraisals of high quality reviews published elsewhere.

- Quality assessed information. The Cochrane Library contains material selected from a wide range of sources, including conferences and publications in languages other than English.

3.1.5 Organised Medical Network Information

Organised Medical Network Information (OMNI) is a collection of UK and some world-wide Internet resources in medicine, biosciences, health management and related topics [16]. OMNI UK is a catalogue of biomedical resources that are essentially sited in the UK. OMNI World is similar to OMNI UK, except that the associated resources described in the catalogue may be situated outside the UK. These resources are usually, but not always, slower to access than resources based in the UK; they can often have a less UK focus than UK based resources. Searches on OMNI are based on the descriptions, keywords and titles of the resources and are not based on the resources themselves.

3.1.6 BIDS

BIDS is an information service hosted by the University of Bath. It first became available in 1991 and is a national service providing widespread network access to commercially supplied bibliographic databases free at the point of delivery. The main objective of this service is to provide, on a not-for-profit basis, a high level of service to allow UK academic institutions and their members access to bibliographic data, scholarly publications and research data [17]. Databases available for access include Embase (an international biomedical information, - Excerpta Medica database - renowned for its international coverage of drug-related research literature) and The Royal Society of Chemistry databases (which includes access to seven specialist resources). It is available on CD-ROM and also through the Internet.

3.1.7 Cliniweb

Cliniweb International is an index and table of contents for clinical information and its main goal is to provide quick and easy access to biomedical information on the Web [18]. Cliniweb is mainly focused on information used by clinicians and health care students. Access is provided by search or browsing facilities, organised using medical subject heading classifications of diseases and anatomy. Cliniweb identifies and indexes information at the level of individual pages on the web. It is hosted by Oregon Health Sciences University in the State of Oregon, USA.

3.2 CLINICAL SUPPORT SYSTEMS

Clinical support systems provide patient specific data for clinicians in the hospital environment. Some of the systems available in the RHH will be described through this section. A typical example of clinical support systems are the Patient Administration System (PAS), the Results Reporting System (RRS), Pharmacy and the Laboratory systems. More recently, patient specific care plans have also become more popular in the hospital environment. All these systems, if they are available within a hospital, hold patient data.

Currently, there are two patient information systems available on all wards of the RHH that can be used by the staff. These are the PAS and RRS systems.

3.2.1 Patient Administration System (PAS)

PAS (Fig. 4) holds demographic information on all patients currently in the hospital along with historical information about spells of hospital care [19]. It generates management information and statutory statistical returns as a by product of its operational processing.

The main modules for PAS are Patient Master Index, Inpatients, Outpatients and the Waiting lists. PAS allows other systems to perform searches on its Master Patient Index.

The Patient Master Index interfaces with other PAS modules enabling registration of patients at any location. It holds basic demographic details and the Patient Master Index (MPI) holds historical information on patient spells of hospital care. All patient details are carried across the other modules, ensuring that all patients have up to date records at all times.

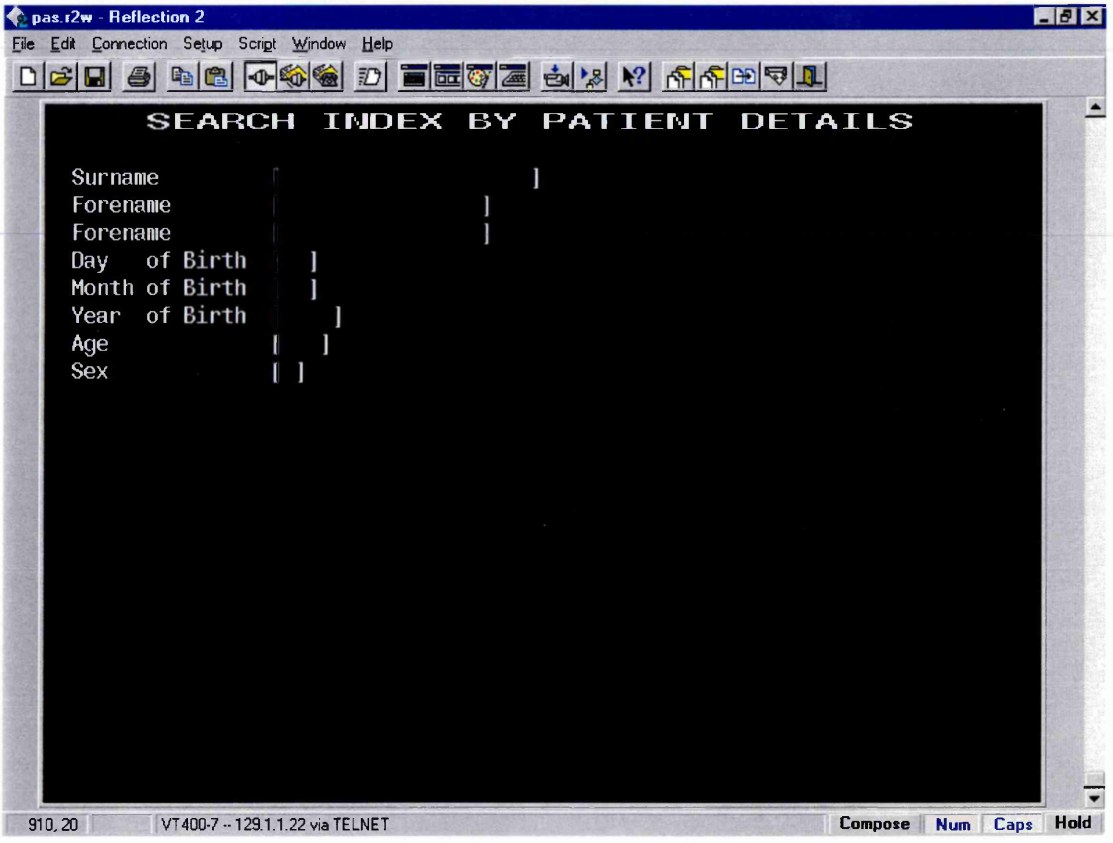

Fig. 4 - PAS System available on the RHH wards.

3.2.2 Results Reporting System (RRS)

The RRS, already described in sections 2.2 and 2.3, also holds clinical and demographic patient data. The RRS system enables clinical staff to send clinical laboratory test requests and receive laboratory test results. The process of obtaining results starts with the clinician completing a request form on the hospital ward, sending it along with a sample to the laboratories and waiting for the result to come back to the ward after the sample has been processed by the laboratory. The computerised Results Reporting System has considerably reduced the delay before clinicians have access to the test result by making them available automatically on the computers in the wards.

The demographic patient data available on its database is validated against the PAS system, thus maintaining more accurate and up to date patient detail information.

3.2.3 Pharmacy and I.T.

A pharmacy system with patient related data is not available at the moment in the RHH hospital wards. Pharmacy is increasingly organising prescription and other internal guidelines for the hospital's medical staff, which could be extremely useful if accessible through the RRS computers on the hospital wards. Also, the Electronic British National Formulary (eBNF) is already available through the RRS system where it can be consulted by clinicians on all the hospital wards (Appendix A).

3.2.4 Laboratories and I.T.

Some of the laboratory data is also becoming available on the laboratory Intranet site (e.g. the on call rota or internal protocols), which would also be useful if accessible through the RRS system on all the hospital wards. The patient data from the laboratories is available on the same system (RRS), thus the clinicians can access the laboratory results at any time of day or night on the hospital wards.

3.2.5 Protocols of Care

Care protocols availability within a hospital organisation is expected to improve the quality of care and reduce the number of litigation cases that arise by standardising the care provided and improving its documentation. However, although care protocols are becoming more and more popular, they are not always available at the required locations. Having them available on computers throughout the hospital would be an ideal way to promote better care for patients as well as providing access to guidance for staff.

4. DEVELOPMENT OF THE WEB

The World Wide Web represents a technology which is designed to integrate information of different types from different sources and from different places into a single user interface - the web browser. Although the World Wide Web was originally designed to allow easy access to Internet facilities, Intranets are now widely used to fulfil similar functions within organisations. An essential element for developing the prototype Clinical Workstation described in this thesis is the integration of reference and patient data. Clearly Internet technologies are a potential powerful tool to achieve this. In this chapter these technologies are examined in detail.

4.1 THE INTERNET

As Killey [20] states, the Internet started in 1960s as a project to ensure that military personnel could communicate with each other in the event of war. The Internet is a network that interconnects government, education and more recently business and commerce. To meet its objective, the Internet was built so that if one part of the network failed, traffic would be routed via another part of the network. The Internet is a network of computers that exists throughout the world. There is no central computer on the Internet. If there is a requirement for a document published by any organisation, it can be obtained directly from their computer, known as a server.

4.1.1 How does the Internet Work?

As McKenzie (1997) explains, the high-speed systems on which the Internet is based use a number of large commercial networks, such as Sprintlink and MCInet. Many other smaller networks are linked into it, but they are run and paid for in independent ways. Basically, it operates through the co-operation of many entities including universities, governments and private organisations. The Internet computers talk to one another using

a protocol called TCP/IP (Transmission Control Protocol/Internet Protocol). Internet software ensures that data is organised according to TCP/IP conventions. TCP breaks up the data into 'packets', adding an address, reassemble instructions and error correction controls. IP breaks TCP into even smaller units, each with an address header.

4.1.2 What is an Intranet?

The most concise definition of an Intranet is "applying Internet technology inside an organisation". Most of the technology that allows organisations to build Intranets is based on the World Wide Web. On the Internet almost any type of computer can be used to talk to any other type of computer completely transparently. This is achieved by using industry-standard protocols that are implemented on many different hardware platforms, operating systems and applications. It wasn't until 1993 that the Internet began to become part of the modern consumer and corporate culture, having previously been the tool of governments, academics and technologists. This was all possible due to the World Wide Web (WWW) project. This project provided users on computer networks with a consistent means to access variety of media in a simplified fashion. Using a popular software interface to the Web called Mosaic[7], the Web project has changed the way people view and create information. The first true global hypermedia network has been created due to the World Wide Web.

However, the Internet is a large environment where one can easily become lost. It provides large amounts of data much of it not validated. Also, being very rich in data, it isn't easily used by the inexperience user. To be able to make it a main resource for reference data it is necessary to provide simplified techniques to search for data. People's need for information includes grouping together data on a specific subject as it is required. It is advantageous to access that data from a single location.

---

7 a mouse-driven interface to the World Wide Web developed by the National Centre for Supercomputing Applications (NCSA).

The best way of finding relevant data on the Internet is by using the available Search Engines in an effective way. They will undertake a search of an Internet database based on the information supplied by the user. They are one of the primary ways in which Internet users find web sites. If relevant clinical information and reference data, which might be available on the Internet, could be integrated in a clinical Intranet and if search engines were used, then it would be possible to have reference data available in the clinical environment of the RHH.

4.2 USE OF INTERNETS AND INTRANETS IN MEDICINE

Reference data in the field of medicine is growing rapidly and its use is becoming more and more popular. Having access to large quantities of reference data which can be used to apply EBM on the Internet will surely make a difference for clinicians and the delivery of the care applied to their patients. As described in section 1.1, in the study accomplished by Wood and Wright [8] the majority of cases studied resulted in a change of attitude from the clinicians after access to information.

Access to the Internet from ward based terminals could give RHH clinicians the opportunity of accessing large quantities of information in all their different areas of interest. The information available is constantly updated and can change and improve as particular research studies progress.

Applying EBM is becoming extremely popular but it requires new skills from the clinicians, including efficient literature searching and the application of formal rules of evidence when evaluating the clinical literature. Intranets could play an essential role, as they can avoid confusion through having too much data displayed and also by keeping users away from unevaluated sources of information.

It can be concluded that Intranets linked to the Internet can easily provide a ward environment with:

- Access to large quantities of data, including reference data which could be used to apply EBM.
- Up to date information at all times.
- Access to only what is needed or required.
- Data which can be maintained to reflect modern clinical practice.
- Studies which are updated as they progress. This would never happen in paper based publications.
- Easy access to authors to clarify or comment on any issues after reading publications.
- Access to data or references found whilst planning treatment – as opposed to waiting to go to a library.
- An infrastructure for sharing knowledge, which is much needed by medical professionals.

4.3 PROBLEMS WITH THE USE OF THE INTERNET AND INTRANETS IN MEDICINE

The usefulness of the Internet in the medical field is indicated by the quantity of data available on the web for this domain. It can also be indicated by the number of users who normally access that data on its varied sites. This information availability can bring users two related problem areas. Firstly, it can be very difficult to find the information needed from amongst such large amounts of data; and secondly, managing to access or download the required data once it is located.

One of the major restrictions in the use of the Internet in general is the lack of an index or contents table. While many information retrieval applications utilise methods of indexing and retrieval, searching for data on the Internet whilst not knowing exactly where to look can become a time consuming task. The automatic generation of indexes or catalogues in

search engines such as *Lycos*, *Altavista*, or *Yahoo* results in a large numbers of retrieved documents, making the results of a search unmanageable [21].

Also, the Internet enables anyone to become an author, providing information. If the information provided is unreliable it can then have a negative impact on its users. This can be overcome by using one of the review services now available. These services select, evaluate or review relevant materials as well as assessing the quality of the material retrieved [21].

4.4 MERITS OF MIGRATING TO A WEB INTERFACE

Patient and reference data from different systems need to be brought together in a single workstation. Within this thesis it is proposed that the best procedure to integrate all information support systems is by exploiting technologies based on the Internet.

With a Web interface, patient and reference data can be presented together in a single workstation. The information that the Internet can offer can be easily identified before starting the development or planning the technological approaches to the implementation. Web browsers and other Internet technologies can help integrating distributed data and provide a consistent appearance to the users.

Many Internet users find the Web frustrating and experience difficulties in achieving effective search results. Intranets can provide one solution to these problems by providing a way of integrating different types and sources of information with a single set of tools and this approach offers significant benefits. Intranets can easily apply technologies developed on the Internet, especially World Wide Web software, to a clinical environment. They provide users with an effective way of conducting their research and accessing up to date information, as well as commenting on the work of others. It allows teamwork, at the same time protecting patient confidentiality. The RRS system holds important patient data which needs to be protected from misuse by unauthorised people.

An Intranet will also be able to provide the clinicians with a means for effective communication.

Being the systems administrator and developer of the RRS System in the RHH, the author needed to plan a way of overcoming the difficulties of training large numbers of staff over a period of years on the same system. Even with an intuitive friendly user interface, the number of staff that required access to the system was large and a training plan was required to be in place from an early stage following its implementation. Continuous staff rotation, means that large numbers of computer illiterate users require training in a busy clinical environment on a routine basis. By having a single interface to a system which would link the various information support and patient support systems, it would be possible to overcome the training constraints experienced with previous introductions of new systems in the hospital.

Many organisations have already embraced the technological support for computer supported collaborative work and are starting to use e-mail, Groupware, Intranets, videoconferencing and workflow. Most of these organisations use these tools to share data[8], sometimes information[9] and rarely knowledge[10]. Our aim would be to share knowledge as well as data between clinicians. Two main questions need to be asked:

- Can the Internet and Intranet together provide relevant, timely, and unique information resources on the ward environment?

- Can they provide users with the required data?

At this stage an overall understanding of the web and its information facilities becomes essential.

[8] data elements. E.g. codes, identifiers or values.
[9] groups of data elements.
[10] data and information that supports decision making.

5. THE WEB AND INFORMATION SYSTEMS

Nowadays the Web contains many different sources of timely and useful evidence from the biomedical literature, which should be a direct component of clinical decision making. However, it is not always easy to find the required information and it is not always organised in the best way (section 4.3). Search engines play an important role when trying to find data on the Internet as they hunt the web searching for the required data. Access to the Internet through search engines is generally well documented. To be able to address this is important and necessary in order to understand what they are and how they work.

5.1 SEARCH ENGINES

Search engines can help to index and provide tables of contents for the data available on the Internet. They create catalogues of web pages, making it easier for users to find the data they require.

5.1.1 How does a Search Engine Work?

According to Sullivan [22], some search engines create their listings automatically. They crawl the web presenting the results so users can search through what they have found. If there are changes to some web pages, search engines are eventually updated with these changes. In general search engines have three main parts:

1. *The spider* - (also called the crawler) visits a web page, reads it, and then follows links to other pages within the site.

2. *The Index* - everything the spider finds goes into the second part of the search engine which is the Index. Also called the catalogue, it is similar to a giant book containing a

reference to every web that the spider finds. If any web page changes, the book will be updated with new information, but this sometimes takes quite a while to happen.

3. *Search engine software* - this is the third part of the search engine which sifts through the millions of pages recorded in the index to find matches to a search and ranks them in order of what it believes is most relevant for the user.

One of the disadvantages of search engines is that if a search engine is used by an Internet page to access other pages, that search engine will be heavily used [22]. This translates into more traffic for sites that are well ranked by the search engines. Sometimes search engines also return a lot of uninteresting and unrelated data. Also, commercially based search engines generally produce more dependable results. They are more likely to be well maintained and upgraded when necessary, to keep pace with the growing web. Search engines are very good and widely used for searching the Internet on general subjects. However, there are different ways of finding information on the Internet for more specific subjects. These are called subject catalogues and they are very powerful tools that are widely used.

5.1.2 Subject catalogues or medical search engines on the Internet

In the area of healthcare there are a number of initiatives working in close proximity with users aimed at meeting the need for access to quality networked information resources. Subject catalogues attempt to arrange the different resources of the Internet in a similar way to a library where resources on similar subjects are grouped together. Catalogues can be browsed as well as searched by users. There are a growing number of evaluated subject catalogues. They have been compiled by individuals, complying with the needs of health professionals wanting to find only relevant and authoritative sources of information.

A few of the available subject catalogues are described earlier in Chapter 3. Some examples of subject catalogues available on the Internet are:

- *Organised Medical Network Information (OMNI)*. Is one of the UK points of access to biomedical (medicine, biosciences, allied health, health management and related topics) evaluated - primarily peer reviewed - resources that are described, indexed and classified. It enables users to browse or search the descriptions of many resources of interest (described in section 3.1.5).

- *Medical Matrix* – provided by the American Medical Informatics Association. One of the most comprehensive lists of evaluated resources of medical information currently available. Medical Matrix is an interface that provides access to digital clinical medicine documents that can be utilised during a patient visit.

- *CliniWeb* – Provided by Oregon Health Sciences University. CliniWeb indexes information at the level of individual World Wide Web pages. It is an index and table of contents of clinical information on the Internet, indexed mainly by terms from the medical subject headings: anatomy and disease trees. It is particularly focused on information used by health care profession students and practitioners (described in section 3.1.7).

- CIC *HealthWeb* – Provided by a team of US health science librarians (Committee on Institutional Co-operation - CIC), organises access to healthcare related Internet accessible resources, providing links to specific, evaluated information resources on the Web selected by librarians and information professionals at leading academic medical centres in the American Midwest. Selection emphasises quality information aimed at assisting health care professionals as well as consumers in meeting their health information needs. HealthWeb is designed for educational purposes only and is not engaged in rendering medical advice or professional medical services.

After looking into search engines it is pertinent to ask:

- Can a search engine or a subject catalogue completely satisfy the needs of the clinical staff working on the RHH wards?

- Is the single Web based Interface going to be appropriate for use on the RHH wards?

To answer these questions, there is a need to find out what data is commonly used for clinical decision making and treatment delivery. To make the most of certified data availability and to find out the main sources of data it is necessary to design tools to support and undertake a study of its viability and potential for use.

5.2 INFORMATION SERVICES ON THE INTERNET

It is obvious that "posting" papers on the Internet makes them immediately available to end readers without having to wait for them to be printed and distributed through traditional methods such as mail services. Also, geographically, the delivery of the papers is much wider and effective. Nowadays, peer reviewed papers are also available on the Internet. The Internet can also give access to all the previous editions of a journal, which may be difficult to get hold of otherwise. Journals on the Internet normally provide access to an index of all previous editions, allowing a quick search of journal paper contents organised by subject.

Information services on the Internet are becoming more complete and when searching the Internet on a subject of interest, users come across *URLs*[11] which suggest other sources available in similar areas that may also be searched.

[11] URL is Uniform Resource Locator. It is a standard way developed to specify the location of a resource available electronically.

5.3 INFORMATION QUALITY ON THE INTERNET

Because of the increased use of the Internet for information access and the explosion in the availability of resources which may be of interest to end-users, a number of services are now available which provide access to selected and evaluated resources. Many existing Internet search tools are inadequate. They produce a large number of references, often on topics that are related or only vaguely related to the search topic.

Nowadays the Internet has potentially given a new meaning to information distribution and access. Almost anyone with a personal computer and a connection to the Internet can become a publisher if they so wish. In the health care field information in peer reviewed journals and that from health sciences departments in universities and government healthcare agencies is valued much more highly than information from other sources. Information which is posted but not subject to peer review is unlikely to be used for educational purposes or to support clinical decision making.

Although in the health care domain there are vast amounts of valuable information, some of which is available on the Internet, valid information is sometimes buried within a medical school or government agency site, making it almost impossible to find. Some of the existing sites have attempted to organise information by topic, resulting in unacceptably long lists of sites covering a very broad context such as medicine or cancer.

5.3.1 Information quality

Checking for information quality is a very important stage of any information system based on web technology in a clinical environment. When extracting the reference data from the published data on the Internet, it is necessary to ask some questions to judge the quality of returned information. This not only applies to the data returned as a result of a search, but the site itself needs to be evaluated for its authority, accuracy, currency, navigation, design, content, scope, audience level and quality of writing [23]. In practice the most important issue to judge is the scientific quality of the material retrieved. That is

most likely to determine its clinical content quality. In order to prove most of these criteria the following questions can be asked [23]:

1. Is the web site presented the official site for an organisation or association?
2. Is the information presented objective?
3. Is the information presented credible and of high quality?
4. Is the author clearly identified?
5. What are the author's professional affiliations?
6. Can the author be contacted?

In the sequence of the presented questions and according to some studies, in most subject review services the source of the material usually acts as an indicator of quality [23]. Another extremely important indicator for information quality is the traditional peer review system, which can also be conducted on the Internet.

5.3.2 Peer Review evaluation and the Internet

Peer review can be defined as a method of evaluating and improving the content of scholarly work by subjecting it to the critical assessment by other workers in the same field [23]. Peer review is commonly used by journal editors of Web resources to receive advice on what to publish.

The Internet has made possible the concept of self-publishing on a huge scale. This has resulted in access to formal and informal articles by its users, which increases the demand for selective and reliable information sources. In other words, peer review is an option which is increasingly being considered and taken up by Internet publishers.

The Internet has also been used to accelerate the process of peer review, providing the means for transmitting the article to reviewers and enabling them to send their comments electronically to the journal [23].

5.4 INFORMATION SEARCHING ON THE INTERNET

Searching the Internet as a source of information is becoming increasingly popular and with the help of available databases and information services, data is now presented in a more effective and organised way than it formerly was. Although searching can be achieved by using general search engines, medical search engines or other information services and specific sites, it can sometimes present users with too many references including information which has not been peer reviewed or evaluated. In a hospital environment, where clinicians will need to apply such information to the diagnosis and treatment of patients, it is of great importance to provide reference information that has been peer reviewed.

Thus, being aware of what is presented to them, or avoiding access to unwanted data would be considered to be good practice in such a special environment. Also, for an inexperienced user, it is as bad not knowing how to find what is needed as it is to be suddenly presented with too many items, especially if they are uninteresting or irrelevant. An Intranet service could filter unwanted information from the Internet and present clinicians with sites containing better quality information for use within their daily tasks.

5.5 INTELLIGENT SEARCH ENGINES

It has become extremely difficult for health professionals to select reference information required for their work without spending an excessive amount of time looking for it. Frequent users of large databases often realise that searching can be a very time consuming task, not only because of the large quantity of data added to it everyday, but also because the maintenance of logical and hierarchical relationships between the data is a very complex task to undertake.

The ideal solution to overcome this growing problem is the concept of an *Intelligent Search Engine*, which would provide relevant information in a short time. It makes sense to consider intelligent search engines as an ideal solution for specialised and very specific fields. The definition of Intelligent Search Engines is considered to be the art of finding the most relevant information among the great amounts of data available on Internet. An intelligent search engine searches other major search engines and returns only the most relevant results for the required search.

6. SOFTWARE DEVELOPMENT, METHODOLOGY AND TECHNIQUES

Within this project a prototype clinical workstation to support EBM needed to be developed. The development of any software system requires the use of tools to formalise the design process [24]. Using formalised methods provides the designer with a clear and precise description of the requirements and the design [25]. However, it is necessary to consider and choose the most appropriate methodology.

6.1 METHODOLOGY AND TECHNIQUES – AN OVERVIEW

There are numerous variations of methodologies and the alternatives considered are listed below:

- *Waterfall Model* - which requires

requirement analysis -> design -> implementation -> testing -> maintenance

(in a sequence).

- *Prototype Systems* - in which

user requirements are checked at different stages during design.

- *Spiral Model* - which consists of

many iterations with users.

- *W Model* - with

only one iteration (design in miniature -> design in full).

- *User-centred design* - which requires repeated cycles of

Development -> Evaluation -> Refine.

A well-engineered system is a system which provides the services required by its users. It should be reliable and efficient and should provide an appropriate user interface [26]. The design and development of a user interface is arguably the most demanding part of the complete system to produce [27]. The designer must recognise that it is not just a piece of software but that it includes a significant component which depends on users. After considering the alternative methods, it was decided to use a user-centred design approach to the development of the prototype Clinical Workstation. This will be described in more detail in the following section.

6.2 USER-CENTRED APPROACH AND ITERATIVE DESIGN

Some principles involved in user-centred design approach are [27]:

- Focus on the users and users' needs, centred on user's issues rather then technical considerations.
- Carry out early testing and evaluation with users to ensure that the system is designed to meet their needs.
- Design iteratively with repeated cycles of design, prototype implementation and testing with users.

The user centred design approach employed in this study is appropriate to provide a sound basis for establishing clear requirements, developing robust specifications, creating early prototypes, and implementing a solution which exhibits ease of use, good performance and satisfaction for the clinicians on the wards.

Interface design is becoming increasingly important for the success of systems. To apply an iterative design, it was necessary to have an understanding of the users, how they do their work and the purposes for which they will use the system. It was also necessary to

find out their needs, prior knowledge and response to the system's early stages prototype: in other words to employ a user-centred iterative design process.

The use of an iterative user-centred approach will result in improvements to the design of the system. However, this approach raises important questions. Some of these are:

- At what level of detail and should the specification be when creating interfaces for different groups of users?

- Is it sufficient to create and evaluate two or three different prototypes – one for the requirements and the remaining for the refinements?

These questions were addressed through the common strategy of developing and evaluating prototype interfaces. The iterative design process allowed for successive testing of approximations of the "final" system. User-centred design allowed an understanding of users, their work, their needs and preferences for the Clinical Workstation and to refine it accordingly. The development of the system was not technically driven, but user driven.

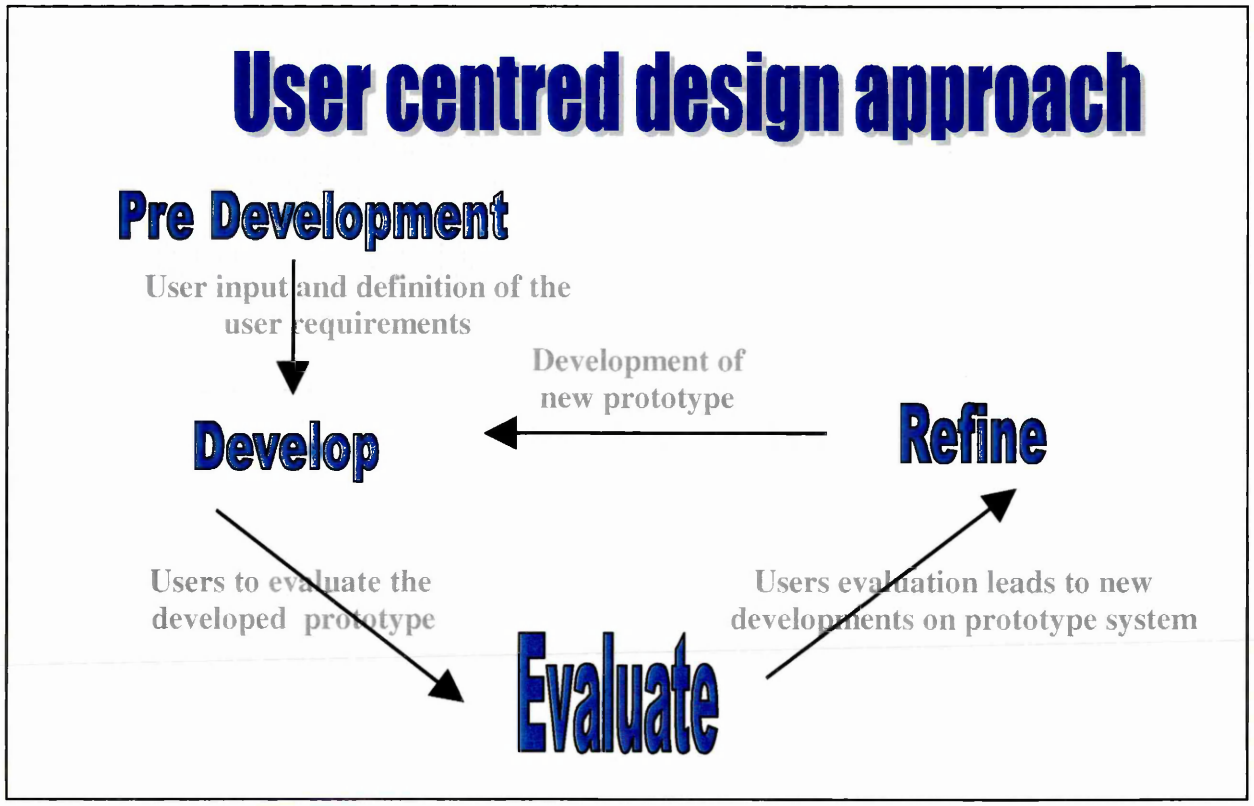

Fig. 5 - User-centred design approach applied - adapted from a typical user-centred design approach [27].

An iterative user-centred design approach (Fig. 5) ensures that a given system or product is designed to meet user capabilities, limitations and aims. It provides the opportunity to analyse users and their tasks so that those system requirements are developed to match user needs. This will:

- Make the system both useful and usable, maintaining user design requirements.
- Test the system for usability, anticipate and avoid user problems.
- Help reduce training problems, as the end system will have a friendlier interface to meet user needs.

- Build interface simulations and prototypes to explore options and evolve new and better solutions.

An iterative user-centred design approach allows the system to be developed and tested at the same time. In order to develop the application correctly, it may or may not be necessary to create different variations of it before a suitable system is achieved.

It is necessary to be familiar with the fundamentals of user-centred design in order to produce an application that is going to have good usability. If the users are not correctly queried in a context which they understand, there is a high chance that the final version will not be exactly what the users were looking for.

Having established that a user centred iterative design development approach was most appropriate for the design process, a strategy for building and evaluating a Clinical Workstation was devised. Part II of this thesis reports on the background and implementation of this strategy.

PART II

BUILDING AND EVALUATING A CLINICAL WORKSTATION PROTOTYPE

7. INTRODUCTION TO THE DEVELOPMENT OF A CLINICAL WORKSTATION TO SUPPORT EVIDENCE BASED MEDICINE

In part I of this thesis, the potential for using information technology to support clinical decision making within an EBM framework was explored. In this section we describe the development of a prototype clinical workstation. From the discussion in chapters 4 and 5, it is clear that the technology associated with the World Wide Web has much to offer in developing systems to support clinical decision making and its assessment for this represents a key element of the development work carried out.

The World Wide Web represents a technology which is designed to integrate information of different types from different sources and from different places into a single interface - the web browser. Although the World Wide Web was originally designed to allow easy access to the Internet facilities, Intranets are now widely used to fulfil similar functions within organisations. Therefore this technology appears to be appropriate for integrating patient specific and reference information. Whilst there are technical advantages in using web technologies which include the integration of information systems and unifying training for staff, a key question remaining is whether a web based interface is appropriate for the clinical environment.

7.1 USE OF THE WEB INTERFACE IN THE RESULTS REPORTING SYSTEM

The RRS holds data from 1995 up to the present day (section 2.2). Its database (SQL server database) is organised by years of results and the demographic data is held in a patient database. The system is constantly updated against the PAS for its demographic data validity, which is also constantly updated by the various reception desks throughout the hospital. The main interface to the system was developed using Visual Basic.

Having considered a Web based interface, it was required to decide on its suitability as a base interface for the RRS System. The technology involved would have to get all the patient data from the system's SQL server database holding patient data from the previous years. After some consideration the tools considered to be ideal were ASP[12] using VBScript[13] and JavaScript[14] associated with Microsoft Front Page. With this technology it would be possible to implement access to all patient data available on the system. It could provide a similar service to that developed for the main version of the RRS already available in the hospital wards. The RRS provides a demonstration EPR for the purposes of developing the prototype Clinical Workstation. In order to evaluate the potential of a Web based interface in the clinical environment, it is necessary to have a demonstration system. To achieve this, it was decided to develop a Web based interface.

7.2 USE OF THE WEB INTERFACE IN INFORMATION SERVICES

After deciding on a Web interface for the RRS system (section 7.1), it was decided to integrate the reference data in a clinical Intranet for the clinicians on the wards. This would enhance the Interface for the RRS System, providing a consistent interface for all the information.

In fact, it could use a lot of the technology already available on the Internet associated with an Intranet to ensure data confidentiality. This would immediately provide access to search engines as well as medical databases. The technology would be implemented in the same way as described in section 7.1.

[12] ASP is Active Server Pages. One of the most common uses for ASP is to create database driven Web based applications.
[13] VBScript is a subset of the Microsoft Visual Basic programming language which is a fast and portable, interpreter for use in World Wide Web browsers and other applications that use Microsoft ActiveX Controls, Automation servers, and Java applets.

7.3 EVIDENCE BASED MEDICINE AND THE WEB

Electronic publications can offer several benefits that could never be achieved through print-based publications. Many of these benefits are dependent on a convenient electronic display format. The Web plays a crucial role in accessing these publications. The Web offers the latest systematic reviews of the medical literature which can help health professionals by summarising and cross referencing large amounts of evidence and explaining differences between different studies on the same subjects. EBM is becoming widely available on the web, making it possible for clinicians to increase their individual knowledge of medicine.

EBM sites are able to provide better interpretation and application for clinical decision making. If there is evidence for a treatment which is proved to be better than another, clinicians need to have access to information about that treatment in order to apply it to the right patients. Accessing EBM on the Internet by individuals is becoming more common and having EBM available at any time on the ward environment of the RHH would be an achievement with many advantages for both patients and clinicians. Nowadays it is easy to see that electronic access from the users' normal work place is the only feasible way to apply EBM in daily use. Information sources for EBM available on the Web are growing rapidly [28].

7.4 INTEGRATION OF WEB BASED SERVICES WITH CLINICAL TASKS

Clinicians, especially medical staff, have constantly to adapt their daily duties to the uncertainty of the cases they come across in a normal working day. To be able to provide an effective and useful source of references to help them apply EBM when treating patients, access to those references would have to be fully integrated with their normal daily duties.

---

[14] JavaScript is a scripting language version of JAVA.

This service, if available at the bedside, could have a major impact on the way clinicians work and, in particular, their clinical decision making. It is important to list some relevant points at this stage:

- It is normally difficult to keep up to date with the relevant literature in a given field of interest.
- EBM is very important for treatment delivery. There is a lot of evidence which is unpublished and unpublished evidence might be important. Unpublished evidence should be internally reviewed within an organisation before it is used to justify patient care.
- Of the evidence available on all the major databases, the average "searcher" can find only a small portion.
- The major bibliographic databases available cover less than half of the world's literature and are biased towards English language publications only.
- Papers, textbooks and reviews that have not been prepared systematically or peer reviewed may be unreliable. So only those which have been reviewed should be available.

7.5 THE NEED FOR A CONSISTENT INTERFACE

Based on this study, a need was identified for the implementation of a system which would contain sources of information to support clinical decision making and patient care delivery. For the clinicians it would be very useful to be able to:

- Access all patient and reference information required for clinical decision making in a single and consistent interface.
- Keep up to date with the relevant evidence which could cover the field of interest of all individuals.
- Access published evidence easily any time it is required.
- Find sufficient evidence on all the major databases in an easy and effective way.
- Access the world's literature in English language publications.

- Find peer reviewed publications.

Information for users is needed so that the requirements for the prototype system can be specified. It will then be possible to integrate the system in a busy ward environment for immediate availability when needed by the clinicians. This work aims at integrating access to reference and patient information through a single user interface – a Web browser – as a method of providing direct support for the delivery of EBM.

8. PLANNING HOW TO GATHER DATA FOR ANALYSIS, SPECIFICATION OF REQUIREMENTS AND FORMS OF EVALUATION

Many studies have shown that poor acceptance of information technology in the clinical environment is primarily due to insufficient attention being paid to users' needs and to the quality of the Human Computer Interaction (HCI) of the systems implemented [26]. To find the requirements for the clinical workstation, an iterative user centred design approach was adopted, as described in section 6. The key elements of this are repeated cycles of prototyping and evaluation. The evaluation, from a user's perspective, needs to measure attitudes and satisfaction with each prototype system implemented. This section looks into methods of gathering data and describes what was done. The results of the experiments are presented in sections 9, 11 and 12.

8.1 WHERE TO FIND EVIDENCE

The requirements for the practice of EBM include defining a patient problem and the information required to resolve the problem. This means conducting an efficient search of the literature, selecting the best of the relevant studies and applying rules of evidence to determine their validity. It also means being able to present to colleagues in a succinct fashion the content of the article, its strengths and weaknesses, extracting the clinical message and applying it to the patient problem. Clinicians need to interpret and apply the results of clinical research and at the same time they need to be sensitive to patients' emotional needs. EBM involves skills of problem defining, searching, evaluating and applying original medical literature to situations day by day. For example, practice guidelines are systematically developed and contain statements intended to assist clinicians and patients with decisions about appropriate health care for specific clinical circumstances. Evidence-based practice guidelines are based on systematic reviews of the literature, appropriately adapted to local circumstances and values, by clinicians [21].

Understanding the complex structure of medical decision making requires an appreciation of the ways in which knowledge, skills, values, and research evidence are integrated into each patient-clinician encounter [21]. The coverage of medical topics by systematic reviews, although expanding rapidly, is still limited. The Cochrane collaboration is facilitating this but needs increasing support and participation to succeed. Investigation into the science of research synthesis will increase the quality, and thus the value, of the evidence found in systematic reviews.

Information technology can provide point-of care access, but clinicians need new skills to use technology. With the advent of "windows" software interfaces, information access from the Internet has become more user friendly for clinicians. While looking forward to these advances, clinicians can and should take advantage of what systematic reviews have to offer now. The *Annals* series will aid in that process by focusing on how to find, assess, use and conduct systematic reviews for clinical, teaching, and research purposes [21].

The user centred design approach was used to support the necessarily complicated process of creating the user interface for the prototype system. Working with the target users from an early stage would help to find what the system would do and at the same time it would be consistent with user needs. Users' feedback would be considered from an early stage, thus the workstation design could be applied to the specific environment proposed at the same time as it could be re-thought at the next stage.

The process of user-centred design is based on thinking about the world from a user's perspective, from the beginning until the final stage. User-centred design is shown as a useful framework for understanding a number of issues and their solutions.

It was needed at this stage of the user-centred design approach to be able to obtain information from the clinicians and investigate their sources for delivering treatment. The evidence needs to come from the clinicians to be accurate. To be able to fulfil the users'

needs the system should be based on the actual information needs of the users involved, not just on the available technology or the area studied. The system must be user driven instead of technology driven. Users can identify criteria or priorities for this information system and they might have certain expectations that they will be able to fulfil with the information system.

Thus, from gathering the requirements up to the prototype development, the system development process was clinical staff driven. Also, it was thought interesting to investigate how similar were the end users' perceptions of the information sources available.

8.2 METHODS OF GATHERING DATA

To be able to gather the correct data from clinical staff, an efficient method was required which would allow data to be collected from a lot of individuals. It was decided to proceed with structured interviews and questionnaires. This section considers both these options and how they should be applied to obtain appropriate data.

8.2.1 Interviews

An interview aims to obtain information of relevance for the specific research in hand. It involves verbal interaction between the researcher and one or more respondents.

"*Personal interviews, allowing a high response rate, direct interaction between the surveyor and surveyed, question clarification, and the elaboration of data through minimisation of unclear answers, is conceptually the superior form of study technique.*" - Chen and Heron [29].

8.2.2 Different types of interviews

According to Stone [30], there are five different types of interviews to be considered:

- *Structured* - the order of questions and the choice of response are fixed precisely before hand.
- *Standardised open-ended* - questions and their order are determined in advance but the responses are freely worded.
- *Semi-structured* - some questions are completely structured and some are open ended. It combines aspects of structured interviews and standardised open ended interviews.
- *Interview guide approach* - questions are formulated on the spot, but cover a set of topics or loosely framed questions.
- *Unstructured* - questions and, consequently answers, are not determined in advance.

8.2.3 Questionnaires

"The ideal questionnaire is brief, attractive, asks unambiguous questions, is interesting and easy to complete, can be analysed with little effort and interpreted without difficulty to provide clear and concise information on which to base decisions, and is exceedingly rare" Martin and Lancaster [31].

Heather & Stone [32] suggest that a questionnaire is a structured schedule of questions which is either self-completed by the respondent or is completed by an interviewer who reads out the questions and records the responses. It is worthwhile spending some time on careful questionnaire design as the result of a study could be useless if the questionnaire design is poor.

Questionnaires are used mostly when it is necessary and possible to determine in advance what questions need to be asked in the study. They are also used if a large number of standardised responses are required and questions are simple and unequivocal. They provide an opportunity for the respondents to feel at ease to express themselves. They

may also be used with large groups, avoiding interference to the way the enquirer would deliver the question or alter the meaning of it and thereby influencing the response.

Systems analysts obtain the essential information about user requirements by using interviews and questionnaires and by observing current practice [27]. The major problem with traditional requirements analysis is that detailed information about the real user activities and wishes was often not collected. Having requirements based on the analyst's specification often results in a non-usable system. After carefully examining alternative methods, the planning of semi-structured interviews was begun.

8.3 OVERVIEW OF INTERVIEWS AND QUESTIONNAIRES APPLIED

Being considered the most reliable type of interview and fitting in with the objectives of this study, the selected type of interview used was a *semi-structured interview*. It is the most restrictive for the interviewer and the respondent, but the length of the interview is controlled and the responses can all be compared and aggregated. The questions are obvious because the purpose of the research is simple and straightforward. Because of this, the result will be answers that can be compared once they are phrased and standardised. It is more appropriate than a questionnaire on its own. Because of the lack of experience of some of the users they may experience difficulties when trying to accomplish some of the tasks. It may also be necessary to clarify some of the questions and some of the answers.

Stone [30] points out some important tips to be followed when planning interviews:

- The interviewer must be sure that he has correctly understood an answer and that it is adequate.
- The interviewer must not answer for the respondent.

- If the respondent requires any type of clarification or any question to be repeated it must be done promptly but in a non-directed way in accordance with the question objectives.
- If the obtained answer is inadequate the interviewer must act towards obtaining an adequate answer.
- If there are more than three choices of answer it is better to use a card so the respondent will remember them.
- To make the respondent comfortable by delivering the questioning in as natural a manner as possible and by appearing interested in his answers.
- Always using the same interviewer will achieve consistency.

Having decided on a method for defining requirements, a need for selecting a method of evaluation from a user's perspective was required. As Wyatt and Spiegelhalter [33] state, in systems evaluation there is a need to measure attitudes and user satisfaction which may be difficult to do formally. It may be appropriate to expose users to the prototype and to observe their activities and reactions along with a semi-structured interview. Applying a combination of verbal comments with observation of reactions might lead to valuable conclusions.

The following section (8.3.1) summarises objectives for the structure interviews in order to determine the user requirements.

8.3.1 Objectives of the semi-structured interviews

Defining the study's objectives at an early stage is very important. The interviews of clinicians must be well planned in order to gather the desired data for the Clinical Workstation requirements. The aim was to:

- Determine where users currently obtain reference data to support the care of patients they are currently treating.

- Identify problems associated with obtaining data to support diagnosis and treatment delivery.
- Prioritise the value of the sources of information most commonly used.
- Identify how much experience medical staff have of using the Internet.
- Identify the awareness medical staff have of information available on the Internet.

The first important stage is defining the objectives of the semi-structured interview. To accomplish this, familiarity with the area of study is required. The next stage of the project was to devise the kind of information required to achieve these objectives.

8.3.2 Plan of semi-structured interview design

The questionnaires to support semi-structured interviews were designed to identify the usage of material in clinical decision making. As part of the structured interview, those involved in the study were shown a demonstration of a web based interface and were asked to assess its potential utility in the clinical environment.

In order to determine the requirements of the Clinical workstation it was considered necessary for the structured interviews and questionnaires to be completed by a fairly large number of clinicians. It was decided to use 40 senior and junior medical staff from the RHH. The subsequent stage was then the evaluation of the different prototypes of the Clinical Workstation.

The questionnaire part of the semi-structured interviews completed by users are available in Appendix C. System prototyping and evaluation were based on results achieved after user consultation. These results, including requirements for the Clinical Workstation, were then applied as described in section 9.

During the first years of their career clinicians need to spend a lot of their working time searching for the correct information to apply treatment. Also, the more senior the staff was, more experienced they were in the process of acquiring the correct information

needed. Based on this it was decided to evaluate the Clinical Workstation with clinicians having different experiences so that the results were based on a general set of requirements. When evaluating the first prototype of the Clinical Workstation it was decided not to go for an enormous set of results but only evaluate those users with more experience, such as the senior staff. They would have the clinical experience and knowledge to be able to perform an evaluation of the clinical workstation according to the objectives of the study proposed on section 8.3.4.

8.3.3 Plan of evaluation questionnaire design

Assessment of the prototype Clinical Workstation's data integrity, searching speeds and efficiency is best achieved by exposing the system to an expert in the field. Medicine contains different areas and specialties and it would be useful to find small groups of doctors or individuals from different specialties and apply the semi-structured interviews to their expert experience of finding relevant data in their specific areas of work.

It was decided to associate a questionnaire with the semi-structured interviews, to gather the user requirements for the clinical workstation. A questionnaire was also thought to be appropriate for a later phase, the evaluation of the system as part of the user centred design cycle.

Questionnaires have many advantages as a means of collecting information [34]. They are cheap to administer in large quantities and can also avoid potential diversions in semi-structured interviews. Simple but well thought-out, they can collect valuable information. However, a misunderstood question can invalidate the data for the whole subject. Questionnaires should be short and the order in which the questions are presented is fundamental. Finally, a good questionnaire should be easy to complete by the respondent and easy to analyse.

8.3.4 Objectives of the evaluation questionnaire

Questionnaires help to obtain large amounts of data from a lot of people. They normally obtain more straightforward results than semi-structured interviews, as they restrict the users in what they can say.

The primary intention was to gather the clinical workstation requirements and to then evaluate the developed system on the hospital wards for its usability and data content. The intentions were as follows:

- Getting feedback on the data links to the Internet.
- The integrity of the system is highly important since it will affect people's treatment and should be taken very seriously.
- The difficulty of usage should also be noted and users must comment on data found on the system: if it is relevant or not and if it is what they were looking for.
- The time involved, when dealing with busy people is also a main factor, so it is required to find out if it is a quick method of searching for good quality data.
- For less experienced doctors, data integrity should be checked with senior staff.
- Identify and prioritise the sources of data that are adequate for searching and consultation.

After researching questionnaire design, the questionnaire was created (Appendix D) and the study proceeded. To successfully evaluate the system the respondents were carefully selected (section 12). They were users of the system with extensive experience of medicine. They were chosen from different specialties in order to perform better testing. The result was a set of 16 senior medical staff from the wards of the RHH and the questionnaires (Appendix D) were applied on this next phase.

As previously referred, sections 9, 11 and 12 report on the results of these experiments, relating together all previously suggested possibilities and establishing which data should be made available for easy access by clinicians and its potential benefit to improve

patient treatment delivery. The questionnaire also helps to evaluate the Clinical Workstation.

8.3.5 Evaluation by observation of the Clinical Workstation in the workplace

Another method that was used for the evaluation process was observation of the system in use in the work place. This causes less conflict with the schedule of work of the clinicians. It could fit in with their activities, as it would be possible to talk with users who already using the system as part of their routine work activity. The observation of activity needed planning but some of the questions to be asked depended on the users' particular activities. The observation was carried out at a later stage of the Clinical Workstation evaluation.

8.4 PROBLEMS ENCOUNTERED DURING PLANNING THE INTERVIEWS AND DESIGN OF QUESTIONNAIRES

While planning the interview and designing questionnaires some problems needed to be resolved. Trying to achieve a reliable set of results is not always easy, and it was necessary to obtain from users a sensible set of results which would lead to an effective design of the Clinical Workstation. There were two components of this, including the selection of a set of users and analysing the results obtained.

A common problem arises when selecting the number of interviewees to contact. To be able to accurately established the correct requirements for the Clinical Workstation it was necessary to extract a sensible sample of data from the clinicians. It was aimed to obtain 40 interviewees and the interviews proceeded, until the target number was achieved. In a later stage of evaluating the Clinical Workstation prototypes, it was decided to distribute 20 questionnaires and to evaluate the returned ones only. It was aimed to get a return of around 15. The final results were based on 16 returned questionnaires.

Another decision to make was on the length and location of the interviews. Appointments needed to be arranged, as busy clinicians needed to be ready for the interviews. All the interviews were carried out in the hospital wards. On some occasions the interview was about to start when the user would be called away to see a patient. If the interview was still at an initial stage, that user was eliminated from the study. Otherwise the interviewer waited for the user to return.

Because the interviews were time consuming, a pilot interview and dummy questionnaire were tried before starting with the intended group of users. This allowed the questionnaires to be trialled, to make sure that they were understood by the users and therefore more likely to gather the correct data.

If the results of any quantitative measurements are to be meaningful, the investigator must be certain that they have been obtained under the correct conditions [34]. To avoid normal difficulties cited in some of the literature, it was important to establish the best way of getting simple and unambiguous answers. If an open-ended question requires a lot more from the interviewee than a closed question, it is also more difficult to analyse [32]. In interviews, open questions can also be tricky when the interviewer holds an opinion on a particular subject, which can influence an answer on that question. The questionnaires included essentially closed questions apart from when an opinion was required. The responses to opinion questions can never be checked. It is never known if interviewees give true opinions on open questions, but this is anticipated.

To ensure data integrity, some of the questions must be validated in a later stage of the questionnaire. It is common to ask the same question twice in different ways in different sections of the questionnaire, which might give an idea if the interviewee is answering the questions accurately. It was decided to apply this as can be seen in the examples in Appendix C (e.g. Q1 and Q11).

8.5 CONCLUSIONS ON SELECTED METHODS FOR THE REQUIREMENTS AND EVALUATION OF THE CLINICAL WORKSTATION

This study has adopted an iterative user centred design approach. The key elements of this are repeated cycles of prototyping and evaluation. The evaluation, from a user's perspective, needs to measure attitudes and satisfaction with the prototype system. Although this is central to the methodology used, it is recognised that it is difficult to do formally [33]. Personal interviews, with direct interaction with the subject, give a higher response rate and allow for clarification of the meaning of both questions and responses. However, questionnaires have the potential for obtaining a larger number of responses [29].

9. DETERMINING THE USER REQUIREMENTS

This section reports on the development cycles of the clinical workstation. The aim of the first cycle was to determine the user requirements and the aim of the remaining cycle was to design, implement and evaluate a prototype workstation which supported access to both reference and patient specific information.

9.1 METHOD OF DETERMINING THE USER REQUIREMENTS

A key property of the Internet and Web technologies is that they integrate data from different sources and different places into a standardised format that can be accessed through a standardised user interface. Clearly, such an approach potentially offers an appropriate platform for integrating reference material with patient specific clinical details. If it is to be successful in the clinical environment then the key questions to be asked are:

- What are the most important sources of information?

- Do Web browsers provide an appropriate interface for accessing both reference and patient specific data within the clinical environment?

In order to address these questions, the opinions of health care professionals within the RHH were sought. The methods employed as described in section 8, included observation of use, semi-structured interviews, questionnaires and a feedback form available on the system. The semi-structured interview was applied on this first stage and was based around an evaluation of the clinical I.T. systems within the ward environment. Prior to the semi-structured interviews, the RRS was modified so that access to the Internet was provided from its user interface. This was used within the semi-structured interview to

evaluate the use of Internet technology for obtaining reference information to support clinical decision making and the acceptability of a web-browser interface. As part of the semi-structured interview a questionnaire was completed which identified the most commonly used sources of reference information to support clinical decision making and problems with accessing them. Finally, the questionnaire identified how much experience the interviewees had of using the Internet and their awareness of the information available.

9.2 SEMI-STRUCTURED INTERVIEW DESIGN

In order to determine the user requirements for information to support the clinical workstation, semi-structured interviews were used, supported by questionnaires (Appendix C). The questionnaires were designed to identify the usage of material in clinical decision making. As part of the semi-structured interview those involved in the study were shown a demonstration of a web based interface and were asked to assess its potential utility in the clinical environment. The semi-structured interviews and questionnaire were completed by senior and junior medical staff from the RHH.

9.3 OBTAINING THE USER REQUIREMENTS

Among the medical staff of the RHH, 40 doctors were approached to take part in the requirements identification process. All of the doctors contacted were co-operative and willing to participate in the experiment. They varied in their professional experience with almost equal numbers of House Officers, Senior House Officers, Registrars and Specialist Registrars being included in the sample studied.

The doctors interviewed all felt that an increased availability of reference material on the ward would improve patient care. From the clinical systems currently available on the wards of the RHH, 90% (36 out of 40) of those interviewed routinely used the RRS.

Part of the questionnaire used with the semi-structured interviews assessed the potential for using a web-browser interface to access both clinical and reference data. 22 of the 40 doctors used in the trial had previous Internet experience. No difference was found in the results for questions relating to the user interface and commonly used sources of both reference and clinical information between respondents on the basis of previous Internet experience. Therefore results are reported for the total group of 40 subjects.

The questionnaire explored problems of obtaining data to support clinical decision making. Of the 40 doctors, 25 identified a problem with finding relevant information and 24 identified a problem of knowing which reference sources would provide relevant information. In addition, 34 of the 40 doctors had a problem with the time required to search for information to support clinical decision making. Doctors were asked to assess the importance of commonly used sources of both reference and patient specific information using a 5 point visual analogue scale.

Patient Medical Record File	5
Clinical Information from RRS	5
Clinical advice from senior medical staff	5
Medical text books	4
Journals	4
Drugs Reference	5
Protocols for care	5
Clinical studies	4
Internal audit reviews	4

Table II - Value of information sources in the routine treatment of patients (Median of 5 point visual analogue scale).

The results are shown in Table II. These show that an almost equal importance was attached to all the sources identified. In addition, the participants were asked to identify

specific texts and other information sources which they commonly used. Twenty-eight different sources of information were identified and these were ranked in order of frequency of citation (Table III). This showed that the BNF (British National Formulary of drugs), Medline, protocols of care and the Oxford Handbook of Medicine were the most commonly used sources of information. All the doctors interviewed stated that they consulted colleagues when they required further information on evaluating the state of a patient or when planning their care.

BNF (British National Formulary)	25	MedLine (Database of medical article citations)	23
Protocols of care	15	Oxford Handbook of Medicine	9
Online Major Journals (e.g. BMJ)	3	BIDS (bibliographic service for the academic community)	2
Lancet (medical journal)	2	Medical text books	2
Oxford Handbook for Acute Medicine	2	Specialist sites	2
Blood Journal	2	Cochrane DB of systematic reviews	1
Library of conditions in picture	1	Guidelines for SHO/HO	1
Email	1	BMA (British Medical Association)	1
British Journal of Haematology	1	Guillians Haem. companion book	1
Haematology sites	1	Harrisons Principles Of Internal Medicine – *Stone, Richard M.*	1
American College of Physicians journal club	1	Pages with names of people on call for different specialities	1
Patient chronological list of admissions and clinical visits	1	Copy of the most recent discharge / summary clinic letters on line	1
Embase (biomedical and pharmacological database)	1	Society of Gastroentereology	1
Newsgroups	1	NEJn	1
RRS (Results Reporting System)	1	ListServers	1

Table III – Information sources identified by users ranked by frequency of citation.

9.4 IDENTIFIED USER REQUIREMENTS

The analysis of the results from the semi-structured interviews provided the inputs to the next iterative cycle of the user centred design methodology. These showed that if

reference information was to be provided through workstations on the wards, then the following must be provided:

- A selection of one or more general medical textbooks, which could be used with rapid access to searching facilities based on subject.
- A link to an online BNF which could be quickly accessed.
- Patient care and investigation protocols in a form which could be made patient specific.
- Medline access with links so that full journal articles could also be accessed.
- Direct access to the major medical journals, particularly the most recent editions

Part of the semi-structured interview evaluated the ease with which clinical users could access Web based information. The results from this suggested that a Web browser interface could be successfully used on the wards.

10. INFORMATION QUALITY AND THE MEDICAL STAFF

As described in section 5, finding the appropriate of reference information is a very important requirement. To complete the knowledge acquired over points 5.3, 5.3.1 and 5.3.2, an informal semi-structured interview was also undertaken with 2 senior medical staff (consultants) from the RHH. From these interviews, it was ascertained that the main points that staff look for when assessing a paper for data quality are:

- Is it peer reviewed?
- What is the type of paper? (e.g. clinical report, research study, review, etc)
- Is it part of a randomised control trial?
- Does it support EBM?
- Does it contain results that could affect the clinical care?

The senior medical staff interviewed stressed that EBM papers (essential research studies in human subjects and reviews) are rated highly as opposed to paper based individual case reports and animal work, which are considered to be of lower value.

If the paper is peer reviewed, grading the scientific quality of its contents as part of the peer review process is very important. They also look at post publication summaries of the paper, their methods of analysis and the source of the publication.

Where the paper was extracted from was considered to be very important for both interviewees, with the Cochrane Collaboration or databases such as Medline being

regarded most favourably. The institution where the work was performed is also an important factor in judging its quality.

The statistics used in the paper they are reading are also relevant. They should be appropriate to the subject matter and provide results which translate to the clinical environment.

They also stated that senior clinicians regard particular author names as being more respected, whereas less senior clinicians do not have the experience to recognise key names for the subject being researched.

11. DEVELOPMENT OF A PROTOTYPE CLINICAL WORKSTATION

The key results from the first semi-structured interview were that the Web provided a suitable interface and that it could contain the main sources identified as suitable for the clinical decision making process. Based on this information and the knowledge acquired on information quality, a prototype for the clinical workstation was implemented with integrated patient and reference information.

The prototype Clinical Workstation demonstrated the integration of the patient specific and reference information within a single user interface. The patient based information was made available by creating a web interface to the RRS.

11.1 A PROTOTYPE CLINICAL WORKSTATION

The prototype Clinical Workstation contained all tools necessary for information management, focusing attention on patient specific consultation (described in section 2.5). Access to Medline references and some of the main biomedical related journals satisfies the *tools for information management*, the use of the RRS system would satisfy the *tools for focusing attention* and access to hospital departmental protocols would satisfy the tools for *patient specific consultation*. The outcome of the semi-structured interviews (Chapter 10) also led to important conclusions about where clinical decision making is based and how it would be affected when staff were able to access sources of useful medical information.

According to Wyatt and Spiegelhalter [33] it may not be possible to achieve the complete user requirements for a system without first building a prototype and requesting users to comment upon it. After this, further prototype systems should be built with user input until a refined and promising system emerges. Evaluation of a prototype system is

essential in order to prove data integrity and that appropriate data is being presented and also the acceptability of the user interface. The evolution of this system needs to be carefully planned and only by applying a thorough evaluation will it return sensible results.

11.2 METHOD APPLIED FOR THE DEVELOPMENT PROTOTYPE OF THE CLINICAL WORKSTATION

The results from identifying the user requirements (Chapter 10) formed the inputs to the design of a prototype clinical workstation which was implemented and then evaluated on the wards of the Royal Hallamshire Hospital. A web-enabled user interface to the RRS was developed so that there was a unified look and feel for the patient specific and reference data (Fig. 6).

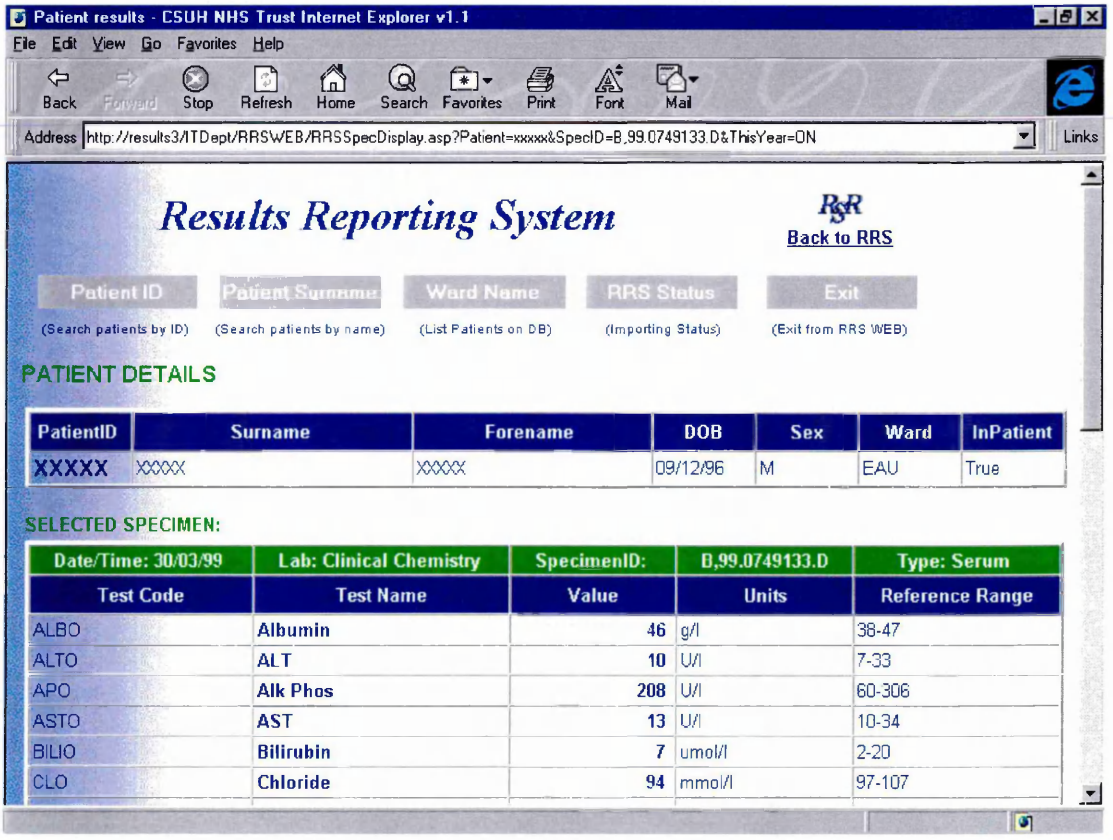

Fig. 6 - An example screen from the web-enabled user interface to the hospital's Results Reporting System showing clinical chemistry results used in clinical decision making.

The top-level navigation screen for the workstation supported links to both the RRS and the most important sources of reference data identified from the semi-structured interviews (Fig. 7).

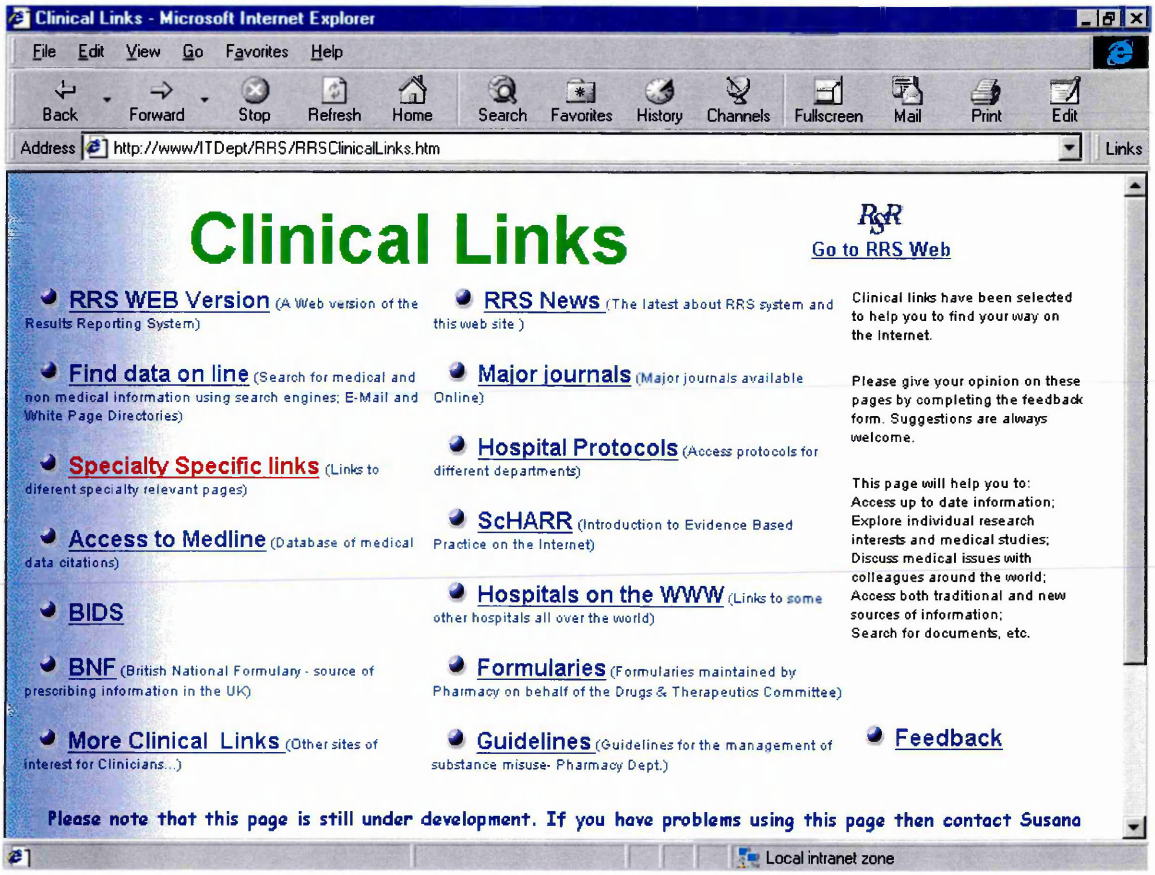

Fig. 7 - Top level navigation screen for the prototype workstation giving access to both patient and reference information. The 'Specialty Specific Links' gives access to the screen shown in figure 3.

The system using the interface shown in Fig. 6 and 7 was implemented and deployed on the wards of the RHH. Data for some of the links provided came from a local Intranet server (e.g. links to the BNF and the drug information system) whilst others were links to

servers on the Internet. Links to the Internet were achieved through a firewall[15] to ensure the security of patient data. Access to reference material was organised using a two part hierarchy with the first level being the medical specialty (Fig. 8) and the second level being the key information sources within that specialty (Fig. 9). The aim was to provide navigation tools that were broad rather than deep to minimise the risk of users becoming lost in a complex series of menus. It should be noticed that the links are not only to specific sources of information (e.g. specific journals) but also to facilities which can identify sources of information (e.g. Medline, Bids etc.). This was seen as a particularly important feature given the difficulties with finding sources of reference material identified in the semi-structured interviews (section 9.3).

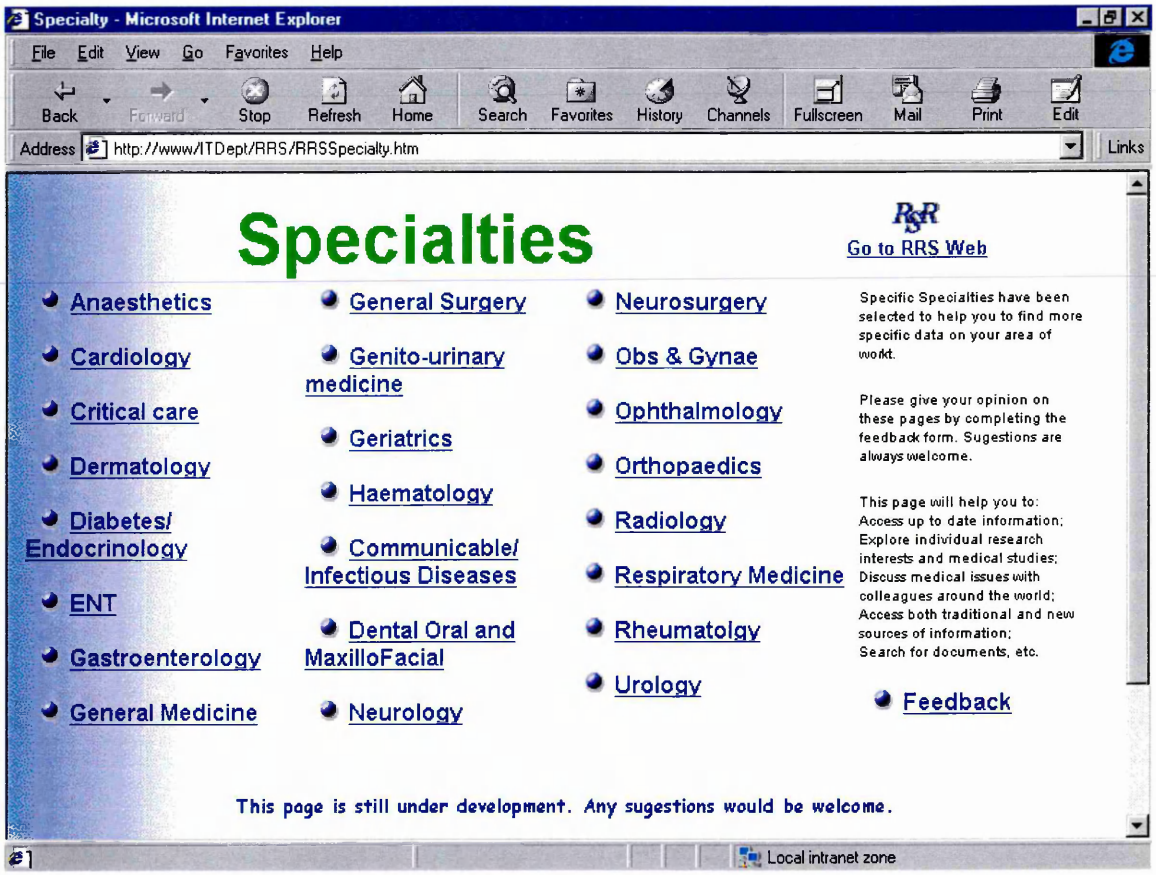

Fig. 8 - The links to reference information organised in terms of clinical specialty.

[15] The main purpose of a firewall is control access to or from a protected network. It is the software and hardware that limits access to a World Wide Web site and provides a degree of security.

On completion of these developments, an evaluation of the functionality provided was carried out. The objective of the implementation was to provide facilities for a large number of clinical users within the ward environment. Therefore as a first stage in the evaluation, a questionnaire was used to assess user satisfaction with the facilities provided.

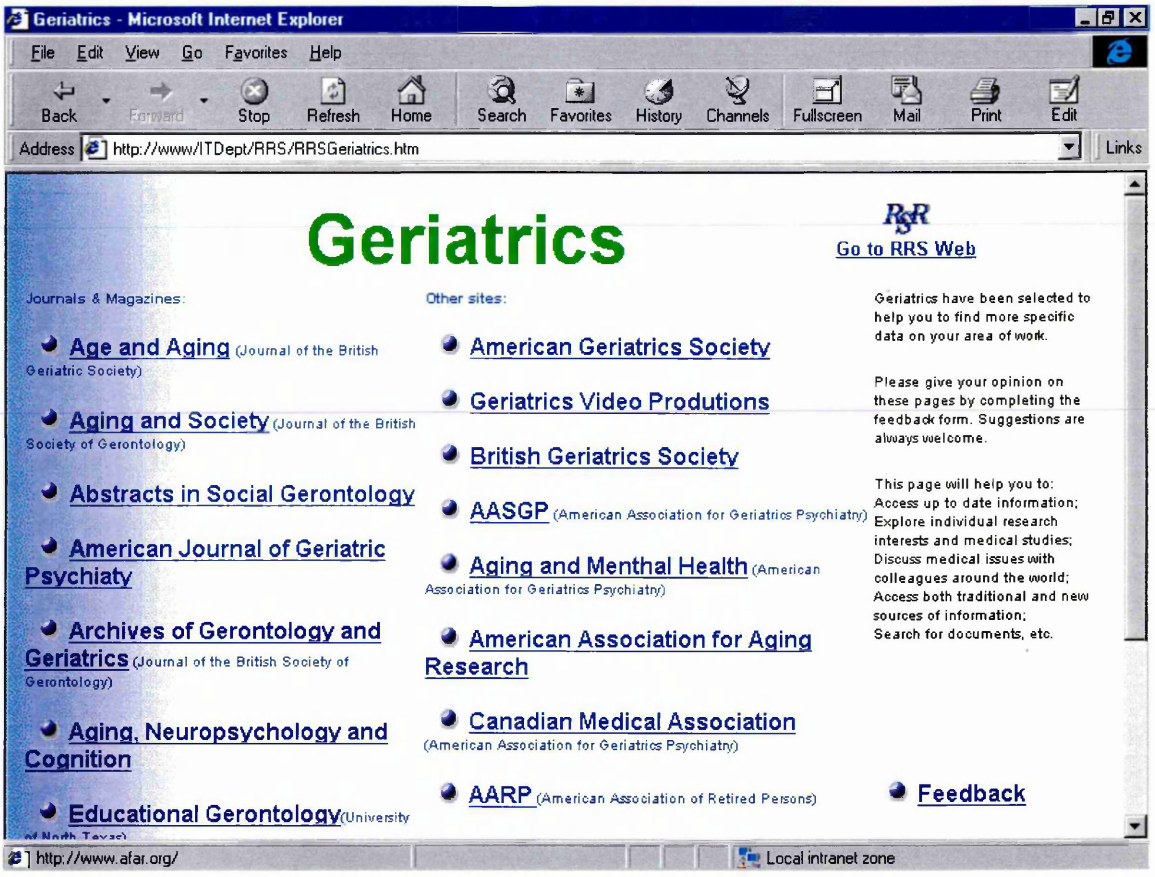

Fig. 9 - The specialty reference sources available on the prototype system for Geriatrics. This screen is reached by selecting the appropriate specialty from the screen shown in Fig. 8.

Doctors who took part in the evaluation were asked to complete a questionnaire within the context of a recent clinical problem where they needed reference information. The questionnaire sought information on the context in which the need for data was generated (e.g. a ward round), the clinical reasons for which the data was required and the reference sources used. Details of the questions are included in Tables IV and V, where the results are also presented.

Sources of data used (includes multiple choices):	
Library	5
Inter/Intranet sources	13
Personal reference books	5
Time to find the required data:	
1 hour or less	11
1-3 hours	5
Purposes of looking for reference data (includes multiple choices):	
Confirm diagnosis	1
Identify treatment options	6
Personal Interest or research	12
Context in which the search for reference data was undertaken (includes multiple choices):	
Clinical concern	10
Clinical investigation	5
Research	3
Ward round	1
Post graduate lecture	1
Basis of this search (includes multiple choices):	
Diseases	10
Treatment	6
Specialty	5
Keywords	4
Drugs	2
Complications (drugs,etc)	2
Use of reference information from the prototype system (includes multiple choices):	
Medical search engines	13
General medical sites	12
Specialty specific Links	13
Medline	16
Medical journals	14
Electronic BNF	7
Other medical sites	2

Table IV - Information source usage identified by 16 senior doctors as part of the evaluation of the first prototype workstation.

12. EVALUATION OF THE PROTOTYPE CLINICAL WORKSTATION

16 senior medical staff from the wards of the Royal Hallamshire Hospital completed the questionnaires (also described in section 8.3). Of the 16 respondents, 1 was from general surgery, 2 from general medicine, 4 from anaesthesia, 5 from ophthalmology, 1 from clinical neurophysiology, 1 from the diabetic centre, 1 from infectious diseases and 1 from neurology. The results of the analysis of the questionnaire are given in Tables IV and V.

Evaluation of information on ward based system ('yes' replies):	
The information provided was useful	11
The quantity of data provided was:	
Too little	2
Enough	14
Too much	0
The quality of data provided was:	
Adequate	13
Not adequate	2
Evaluation of navigation strategy ('yes' replies):	
Information on internet was easy to search and find?	13
Information accessed through the system was easy to search and find?	9
Was it easy to find specific information once an inter/intranet site was selected?	14
Is the information once found in a format that is easy to use?	15
Did the information retrieved fulfil expectations?	13
Was the information found appropriate to the problem identified?	13
Should the clinical links be expanded?	15
Do you prefer searching for data on computers rather than in books/ libraries?	15
Compare gathering data on the prototype system with the traditional methods ('yes' replies)	
The prototype system is better	14
The prototype system is more effective	14
The prototype system is quicker	14

Table V - Results of the evaluation of the first prototype clinical workstation by 16 senior doctors.

12.1 DISCUSSION OF THE RESULTS

The results from the questionnaire (Table IV) showed that the majority of respondents used the inter/intranet facilities provided through the prototype system as a source of reference data. To a certain extent, the importance of reference information as a routine part of a senior clinician's working routine can be seen from the fact that about a third (5 out of 16) spent between 1 and 3 hours searching for information on one topic. The user requirements identified that searching for reference information was a significant problem. The results of the questionnaire (Appendix D) confirm this finding, since all of the respondents cited Medline as one of the facilities in the prototype system they used and the majority also used one of the medical search engines. Two conclusions can be drawn from these findings. Firstly, any tools which can significantly reduce the time spent searching for reference information must improve working efficiency; secondly, if EBM is to play a significant role in routine patient care then efficient tools to search for reference information must be developed. This view is further supported by the majority of respondents citing 'personal interest or research' as one of the purposes of obtaining reference data whilst 'clinical concern' and/or a 'clinical investigation' were the most commonly cited contexts in which the search was performed. These responses suggest that the use of reference data is currently part of an ongoing continuous professional development activity rather than one which is integrated into the clinical decision making process. Clearly, improving the search facilities must be a priority in the next prototype. The user requirements identified the BNF drug reference as one of the key sources of reference information. However, only just under half the respondents (7 out of 16) used the on-line version provided in the prototype system. In view of the importance of the BNF in clinical decision making, this finding requires further investigation.

The questionnaire not only aimed at identifying what facilities from the prototype system were used, but also at subjectively evaluating its value and acceptance. The majority of the respondents (11/16) used the prototype system as a source of reference information. One problem with intra/internet resources is that it is possible to make a large quantity of

information available but that in doing so finding specific information becomes very difficult. The great majority of respondents felt that the quantity of data provided through the prototype was appropriate to their needs (14/16). Perhaps more importantly, the majority of respondents (13/16) felt that the quality of data was satisfactory. This is particularly important if the information retrieved is to be used for clinical decision making (section 5.3).

The tools provided for searching the Internet for specific information were generally found to be satisfactory (11/16), however the questionnaire identified more general problems of accessing information through the system, since only 9 out of 16 were satisfied with the tools provided. Of the remaining 7 respondents, 3 made no reply which was identified in the analysis with a 'no' response. The remaining 12 responses were partitioned on whether the respondent had familiarity with the RRS. 9 routinely used the RRS and of these 7 expressed satisfaction in the way reference information was accessed through the prototype system. This suggests that familiarity of use may play an important factor in acceptance.

12.2 CONCLUSIONS ON EVALUATION

The results of the questionnaire, which evaluated the prototype system, showed that the majority of the doctors who took part were satisfied with both the quantity and quality of information provided. They judged it to be a better, more effective and quicker method of accessing reference data.

One key finding in the user requirements was the value of inter-professional communication in evaluating different therapeutic and investigation regimes. Whilst not part of the current project, it is clear that future developments would have to include facilities for collaborative working amongst health care professionals (as described in section 1.2). A simple way of achieving this initially would be through internal use of newsgroups, which would allow a detailed set of user requirements for the functionality

to be determined. Also email access is already widely available and is provided by RRS machines on the wards.

The need for an effective method of searching for reference material was clearly identified in the user requirements. However, this need was not completely satisfied by the functionality provided in the prototype system. If the workstation is to actively support clinical decision making within an EBM framework, then reference data must be directly accessed from the patient data through some form of automatically generated hypertext link. The results of the evaluation of the prototype clinical workstation (table IV) suggest that a keyword search based on diseases and treatments would be a high priority for the next prototype. Single terms could be used to access locally defined protocols of care [35]. However, complex combinations of terms with automatic contextual reasoning would be necessary to use such an approach for searching large information resources such as Medline if a small number of highly relevant information sources were to be identified.

The BNF drug reference was identified in the user requirement as one of the key sources of reference material for clinical decision making. However, less than half of the doctors who took part in the evaluation used it. This surprising result also requires further investigation. One possibility is that the information is often required as part of prescribing a drug. Since the drug prescription cards are currently paper records, it could be that the information needs to be available in the same physical location as where drug records are stored. A partial task analysis could be of value in investigating this finding further.

When using Internet sources to support clinical decision making it is essential that due regard is taken of the quality of the information provided (section 5.3.1). There is no automatic requirement for peer review as there is in the quality medical journals. Within this study, explicit navigation paths were provided only to 'approved' medical sites where the information provided had been peer reviewed. There is however, nothing to stop users accessing any material on the Internet. A logical extension of integrating EBM

into clinical decision making is that the sources used to support a particular decision ought to be referenced as part of the patient record. Clearly, this will not occur unless reference data is integrated with an electronic patient record. A possible way to implement this would include implementation of hypertext[16] links into reference data on some key words such as medical conditions or abnormal results associated with particular situations. This would be accessible by immediate selection of hypertext links, resulting in a total integration of reference and patient information.

If this integration were to occur, then it would offer the potential for rapidly producing a large volume of reference material based on clinical experience which could be systematically reviewed in a manner similar to that used in the Cochrane Collaboration and then rapidly disseminated. This would make clinical decision making within an EBM framework more viable since the focus for reference information would shift from academic studies to clinical practice.

12.3 FURTHER DEVELOPMENT CYCLES

As a result of working with clinicians it was rapidly learned that taking busy people away from their routine tasks was quite a task in itself, so it was decided to evaluate the system for the next iterative cycles on the basis of observation and the feedback form provided through the system.

The results of this evaluation are not reported in this thesis as this is considered to be outside of the scope of this study. However, use of the system is rapidly growing with promising evidence of improvement with each refinement.

[16] a basic concept behind the Web whereby one resource can be linked to any other information elsewhere in the Web.

PART III

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

13. CONCLUSIONS

This thesis has described the development of a prototype clinical workstation to support Evidence Based Medicine. So far the system has only been evaluated among senior medical staff and requires further evaluation by junior medical staff, although they are already currently making use of it. It must support clinical decision making for both senior and junior medical staff. The evaluation is to be finalised as described in 13.3.

So far there has been no attempt to evaluate changes in working practices which may result from use of the clinical workstation. However, if the time required to gather information for clinical decision making, in particular reference information, is reduced, then working efficiency should increase. It may also be speculated that integrating a clinically based search engine with specific patient information would be beneficial. This would allow for the integration of research data and patient medical history.

Being a teaching hospital, the RHH should promote research and the clinical workstation should support this through the provision of up to date patient and reference information at any time.

Looking at the original questionnaire, one of the sources of data identified to support clinical decision making was communication between professionals. The current prototype clinical workstation does not support this. However, its importance in clinical decision making means that developing computer supported collaborative work must be a high priority in the next iterative cycle of the user centred design process.

Using the information generated from the informal interviews with users, the questionnaire and the feedback form provided on the system, another development cycle is being applied to the interface. The prototype system is currently in routine use throughout the CSUH Trust (RHH and JHW) and it already has more than 600 users, consisting of senior and junior medical staff, senior and junior nursing staff, pharmacists, laboratory technicians, some ward clerks and medical secretaries.

13.1 SUMMARY OF CONCLUSIONS

The main concluding points of the work are summarised as follows:

- The Clinical Workstation provides the information needed to assist clinicians both in the clinical decision making process and in obtaining information to support the clinical learning process.
- The result from the user evaluation has shown that a user centred iterative design approach is appropriate for the development of this type of system.
- The Clinical Workstation provides a successful means of integrating information support systems in a single user interface.
- A unifying interface design has been shown to minimise user training.
- The Clinical Workstation provides the basis for further work on making information services available in an effective way in clinical environments.
- The work is now at a stage that could be generalised and applied in other teaching or general clinical environments.
- Some of the RHH wards have recently initiated ward rounds which aim to directly apply EBM to patient care - e.g. Intensive Care Unit (ITU) and High Dependency Unit (HDU). The successful development of the EBM ward rounds into the hospital routine for that department has already encouraged other departments (e.g. gastro-enterology) to show interest in this approach with the same objective.

13.2 THE FUTURE

The major objective for the future of the prototype clinical workstation will be to decrease quantity and increase quality of reference data available through the system. Information accuracy and reliability requires a detailed and meaningful review of the quality of the different sources. Recent improvements in data availability on the Internet leads one to a question:

- Why have paper records of data when all records could go on the Internet?

Having a paper copy of a document however, is a way of registering work and getting it peer reviewed. It also acts as an archive and has a means of distributing it to those researching in the same area through, for example, libraries. Finally, it should also be remembered that documents available through the web might be longer and may include more data or links to other relevant sources. They can be accessed by clinicians and delivered to anybody in very little time. It will inspire authors to improve their own research.

At this stage another question should be asked:

- Will editors in general be able to keep up with rapid changes in publishing technology?

The future of information sources might be one of better service provision through the Internet. Lower costs, good quality, updated data and greater choice might be the best combination required by the users.

13.3 AN EFFECTIVE APPROACH TO TRAINING CLINICIANS

It has been suggested that using a user-centred design approach helps to overcome some of the training problems as well as delivering a more effective system to its users. Having large numbers of users to train has been a demanding task over a period of years. This is an ongoing problem as staff changes. Therefore an effective training plan will become part of the work of the systems administrator. The user passwords issued and validation of information provided by staff is a task already in hand since all users need to be authorised to use the system.

Clinician rotation takes place every 6 months and there is an induction week to introduce new medical staff to the hospital in general, including I.T. access available within the hospital. Currently, the system has large numbers of new users every 6 months, making it

difficult to arrange individual training sessions. The training plan includes the following elements:

- Most clinicians attend induction sessions organised by the Postgraduate Medical Education department (PGME). The system administrator presents a group session, issuing passwords in advance with the help of the I.T. administrators.

- Others needing access to the system, but who have joined the hospital outside these periods either as members of training groups or alternatively by using SMS[17] remote access to the facilities and guidance by telephone.

- Some qualified staff have been trained to issue access to the system to all the nursing staff and some of the medical secretaries.

- The RRS help line also serves as a first contact and this is always available to a new user.

[17] SMS – System Management Server. SMS provides benefits such as distributing install and update software and files to servers and clients and managing applications run over the network remotely.

14. FURTHER WORK - GUIDELINES FOR OTHERS AND RECOMMENDATIONS

In the light of the previous sections of this study it was found that:

- The medical field is a very interesting area of study with potential for a lot of improvement by exploiting new technological applications. By only slightly changing the way work procedures are implemented, technological applications can instantly save a lot of time or give better results and access to information. With so much information available on the Internet, such changes in working practices need to be considered on a regular basis.

- The application of good HCI Methods in the development of clinical systems is often neglected. Making more use of such methods will result in more effective, usable systems.

- Clinicians are busy at all times, thus getting the correct system requirements becomes a difficult phase of all projects. If, when a first evaluation takes place, the users are not completely disappointed with the results or can see that potential of a future system to benefit their interests, they will collaborate in later phases of development.

- The user-centred design approach to the development of systems to be implemented in the clinical environment has proved to be appropriate for this project.

- Structured observation techniques are recommended as being the most compatible with the evolution of systems in the clinical field, while concentrating on information accessibility and communication. Most of the clinicians do not have much time available to give to the analyst.

- Careful selection of a representative group of the majority of the users to evaluate in the different phases of the approach is important. This will ensure a more sensible set of results for analysis.

- It will be useful to continue with the evaluation cycles and interesting to report on the results. The work in the RHH will carry on, with its busy users, for the next system's prototype. Clinicians are busy but they will try to collaborate since they understand that a more helpful and easy to use system is more likely to result.

The work involved in this project has provided very good experience for learning about the clinical environment. Project planning, evaluation, prototyping and system management, as well as the technical techniques and knowledge involved in developing the various prototypes were some of the important experiences acquired during the project.

14.1 USE OF THIS TECHNOLOGY IN FURTHER APPLICATIONS IN THE WARDS: TOWARDS AN ELECTRONIC PATIENT RECORD

Being able to use this same technology in further applications in the wards should encourage rapid progress towards a full EPR system.

A future EPR should include a complete pharmacy system, with drug prescription as well as management of patient care and imaging. A longer period of time would be required for prototyping and integrating these systems. A full EPR will also require reference searching to be fully integrated within the main patient system. Bar-coding for easier identification of patients and samples is a future area of work to be considered.

There is a great possibility that a fully implemented EPR will be part of the future information systems available in the CSUH trust, as it is already planned to implement some of the proposals described above.

14.2 SUGGESTED IMPROVEMENTS TO THE CLINICAL WORKSTATION

A better Clinical Workstation could be achieved if some of the following features were implemented:

- Currently for the departments of radiology and nuclear medicine, it is only possible to include textual reports on images. It would enhance patient care if imaging as well as reports were available within the system.

- An intelligent search engine, fully integrated within the Clinical Workstation, which would provide users with the right reference data only for the highlighted condition.

- Bar-coding, especially welcomed by the various laboratories, would be useful, as this would reduce the time required for samples to be delivered and processed by laboratories.

The next cycle of the Clinical Workstation is already in implementation. The system's development and evaluation will continue after this study report is finalised.

15. REFERENCES

[1] "Medical Informatics: An Emerging Discipline with Academic and Institutional Perspectives" - R.A. Greenes, E.H. Shortliffe, *Journal of the American Medical Association* 263(8):1114-1120, 1990.
http://smi-web.stanford.edu/pubs/SMI_Abstracts/SMI-87-0180.html

[2] "Medical Information on the Internet" - R. Kiley, Churchill Livingstone, 1996.

[3] "The Internet as an information source for geriatricians" - J. Glowniak, *Drugs and Ageing*, vol.10 no. 3, 1997.

[4] "Groupware and Social Dynamics: eight challenges for developers" - J. Grudin, *Communications of the ACM*, vol. 37- no. 1, Jan. 1994.

[5] "Groupware, Some Issues and Experiences" - C. A. Ellis, S. J. Gibbs and G. L. Rein, *Communications of the ACM*, vol. 34 no. 1, Jan. 1991.

[6] "The computerised patient Record" - Scott Wallace, *Byte magazine*, May 1994.

[7] "The Twenty-eighth Mary McMillan Lecture: On decision making. Phys Therapy" - B.J. May, American Physical Therapy Association, 76: 1232-1241, 1996.

[8] "The impact of information on Clinical Decision making by general medical practitioners" - F. Wood, P. Wright, 1996.
http://www.shef.ac.uk/uni/academic/I-M/lecturer/paper11.html

[9] "Computer programs to support medical decision making" - E.H. Shortliffe, *JAMA*, Vol. 258, no 1, July 1987

[10] "The Medical Literature as a Resource for Evidence Based Care" - K.A. McKibbon, N. Wilczynski, R. S. Hayward, C.J. Walker-Dilks, R.B. Haynes, Health Information Research Unit, June 1996.
http://hiru.mcmaster.ca/hiru/medline/asis-pap.htm

[11] "The Doctor's Internet Handbook - Samples and Contents" - Robert Kiley, Information Service Manager, The Wellcome Trust, London, Oct. 1998

[12] "Systematic Reviews: Synthesis of best Evidence for Clinical Decisions" - D.J. Cook, C.D. Mulrow, R.B. Haynes, American College of Physicians, *Annals of Medicine*, 126:376-380, March 1997.
http://www.acponline.org/journals/annals/01mar97/bestevid.htm

[13] "Shaping the world of electronic health records. What is an Electronic Patient Record" - *Medical Records Institute*, 1998.
www.medrecinst.com/oldsite/MRImain/levels.html

[14] "An Information Strategy for the Modern NHS 1998–2005: Supporting patient care" - NHS Executive, 1998

[15] "The Cochrane Library" - NHS Centre for reviews and dissemination, The University of York, © Copyright: The Cochrane Collaboration 1999.
http://www.update-software.com/ccweb/cochrane/revabstr/ccabout.htm

[16] "OMNI: Organised Medical Network Information" - Greenfield Medical Library, University of Nottingham.
http://www.omni.ac.uk/

[17] "BIDS - Bath Information Data Service" - Library and Learning Centre, University of Bath.
http://www.bids.ac.uk/Tfedocs/info.htm

[18] "CliniWeb: Managing clinical information on the World Wide Web" - W.R. Hersh, K.E. Brown, L.C. Donohoe, E.M. Campbell, A.E. Horacek, *Journal of the American Medical Informatics Association*, 1996, 3: 273-280.
http://www.ohsu.edu/cliniweb/about.html

[19] "Patient Administration System (PAS)" - Total Care, Training Guide, HBO & Company, Redditch, Worcestershire, January 1998.

[20] "Medical Information on the Internet: A guide for health professionals" - R. Killey, Churchill Livingstone, 1996.

[21] "The good, the bad and the ugly: Internet review sites", A. Cook, A. McNab and B. Anagnostelis, Online information 96, December 1996: 33-40
http://omni.ac.uk/agec/iolim96.html

[22] "Search Engine Watch" - Danny Sullivan, Copyright © 1996-99 Internet.com LLC.
http://searchenginewatch.com/wgtse.htm.

[23] "Peer review on the Internet: a better class of conversation" - C. Bingham, *The Lancet*, 351 (Supplement 1): 10-14, 1998

[24] "Information Systems Development: Methodologies, Techniques and Tools" - Second Edition, D.E. Avison /G. Fitzgerald, 1995.

[25] "Human-Computer Interaction – Psychology, Task Analysis and Software Engineering" - P. Johnson, McGraw-Hill Book Company Europe, 1992

[26] "Software Engineering" - I. Sommerville, Addison-Wesley Publishers Ltd, Fourth Edition, 1992.

[27] "A Guide to Usability" - The research and technology initiative, The Open University in association with the Department of Trade and Industry, Milton Keynes, 1990.

[28] "Getting the evidence" - Arnel de Serra, *Health service Journal*, 28 May 1998

[29] "Information seeking: assessing and anticipating user needs" - C.Chen and P. Hernon, New York, Neal Shuman, 1982.

[30] "Crus Guide - Interviews" - Sue Stone, Centre for Research on User Studies, University of Sheffield, British Library Board, 1984

[31] "Investigate methods in library and information science: an introduction" – J. Martyn and F. W. Lancaster, Information Resources Press, 1981.

[32] "Crus Guide - Questionnaires" - P. Heather & S. Stone, Centre for Research on User Studies, University of Sheffield, British Library Board, 1984.

[33] "Evaluating medical expert systems: What to test and how?" - J. Wyatt and D. Spiegelhalter, *Medical Informatics*, Vol. 15 - no 3, 1990

[34] "Human-Computer Interaction, theory and practice" - F. Maddix, Ellis Horwood series in computers and applications, 1990

[35] "SGML for Medical Records – The Oswestry Pilot Project" – Andrew Roberts FRCS DM, Autumm, 1997,
http://www.keele.ac.uk/depts/rjah/sgml/sgmlmain.htm.

16. APPENDIX A

SCREENS SHOTS FROM THE RESULTS REPORTING SYSTEM

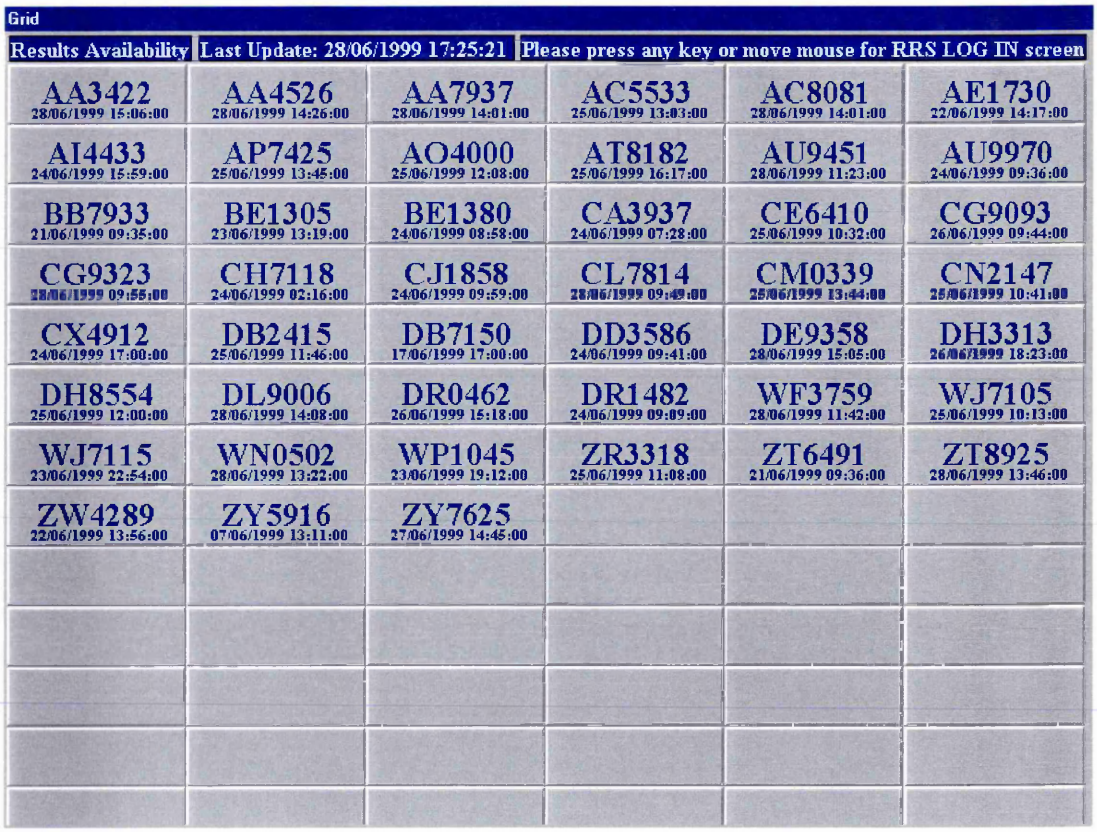

Fig. 1 - RRS Screen saver.

This screen automatically loads when the system is logged off. It notifies the users of any new results available. Each square contains a Patient ID number as well as the latest date and time of a result arrival for that patient.

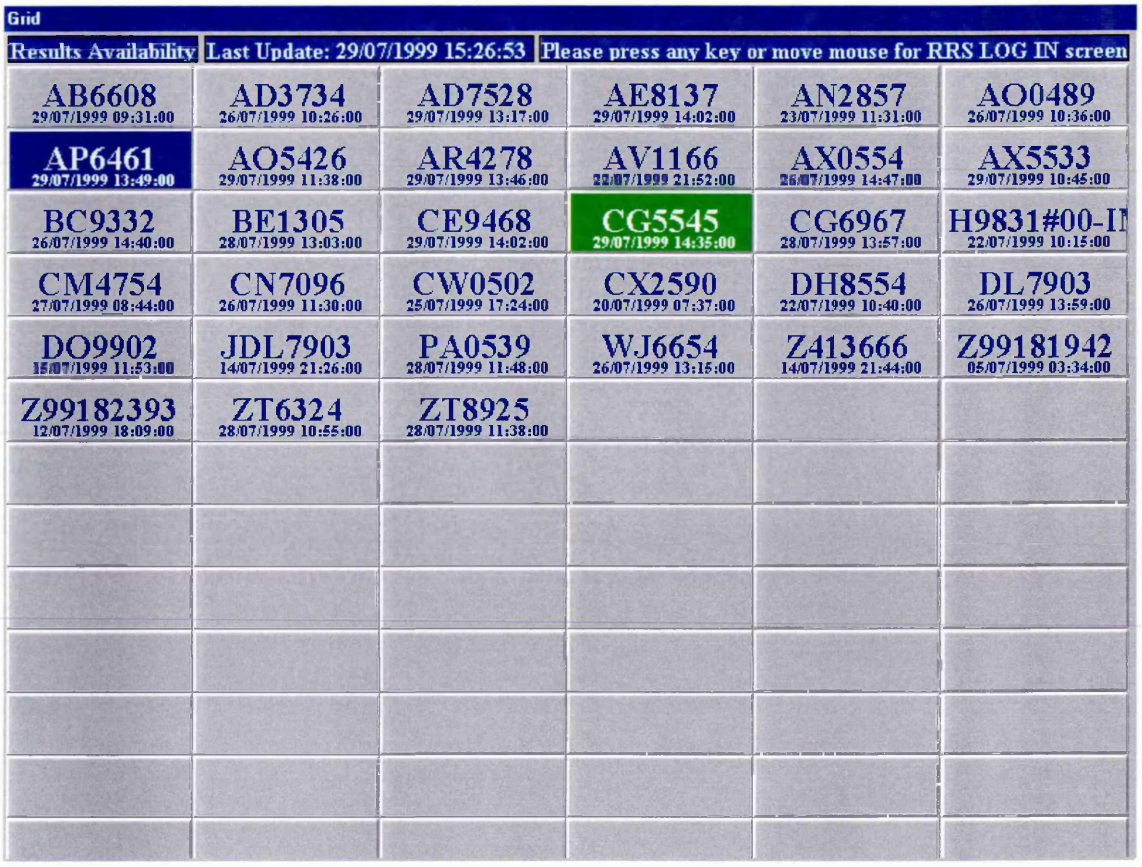

Fig. 2 - RRS Screen saver.

If a new result becomes available, the relevant patient number background becomes coloured, using a different colour for each laboratory. This way, the result can be immediately identified by clinicians waiting for it, even without a login. In this example there are new results for chemistry and coagulation (blue and green).

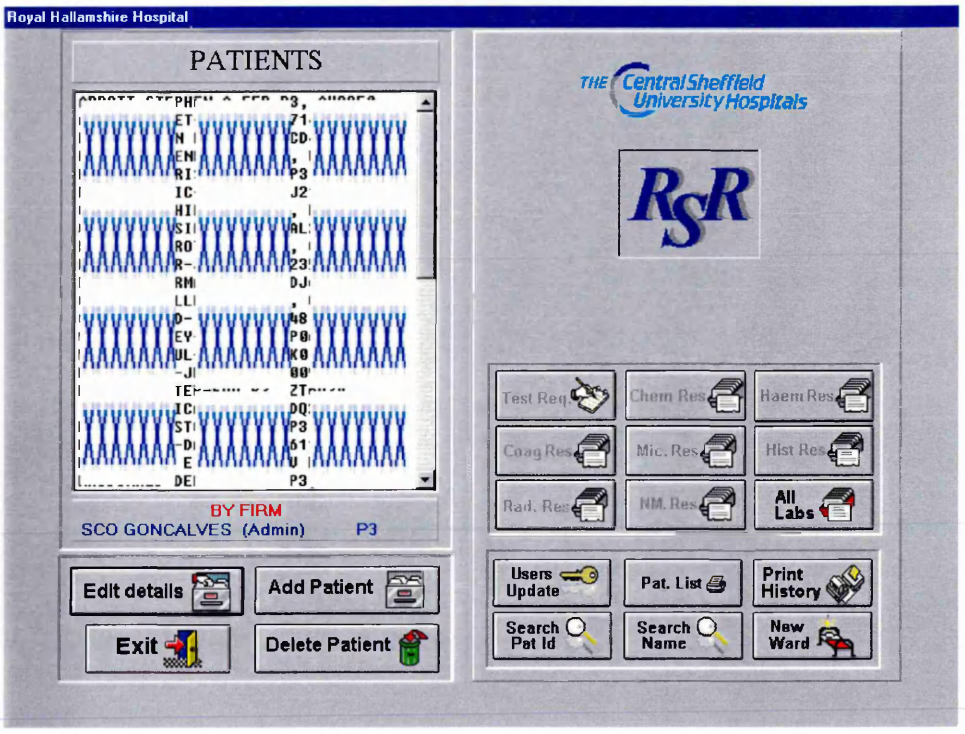

Fig. 3 - List of all patients for a user on RRS system available on all the wards of the RHH wards

Displays the list of patients available for the specific clinician, which is normally a combination of a ward and a firm (in Fig. 3 the displayed ward is ward P3), after a logon. After selecting a patient, the requests screen or any results screens can be accessed.

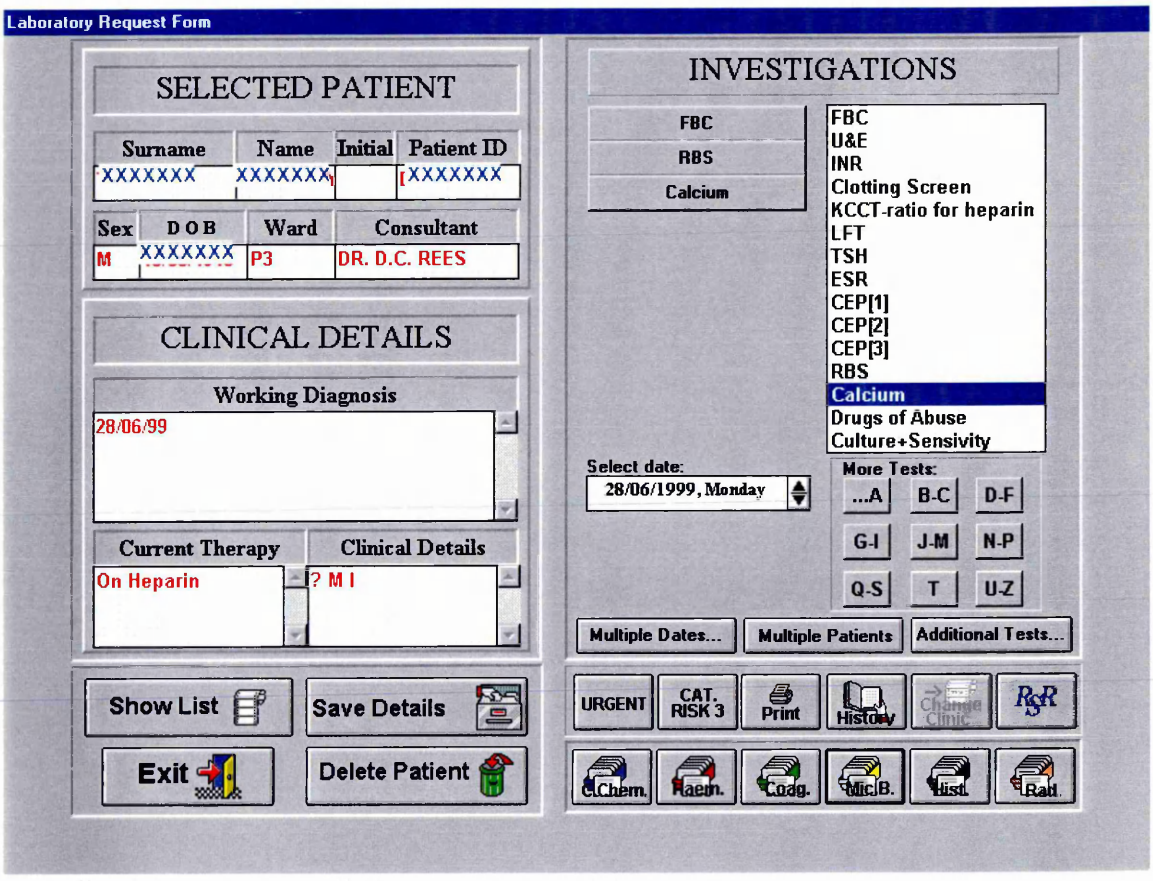

Fig. 4 - Test request on the RRS system

The requests screen also contains an extract of the patient demographic data. This screen allows clinicians to print out their forms for a test request. It also allows access to any results screen for the different laboratories as well as the history screen.

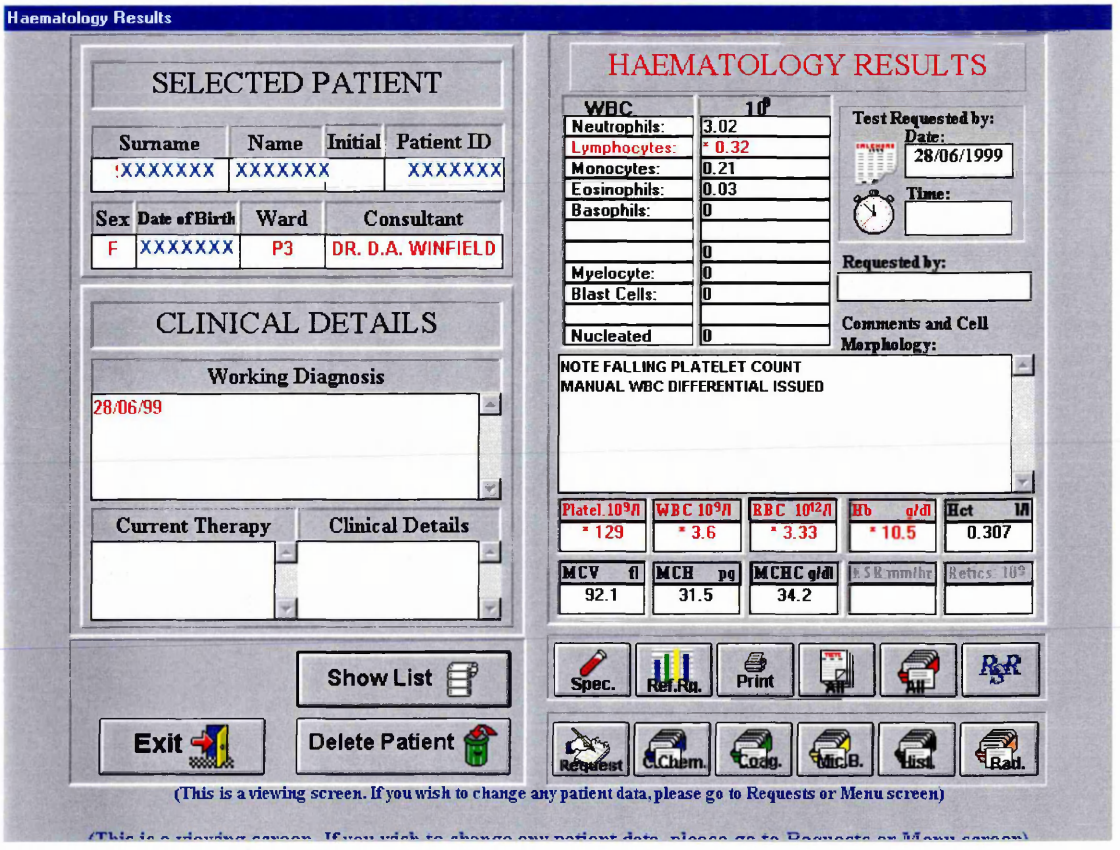

Fig. 5 - Results for haematology on the RRS system

Results for a specific patient for haematology. All the results displayed in red are abnormal. The latest sample available for that patient is displayed by default.

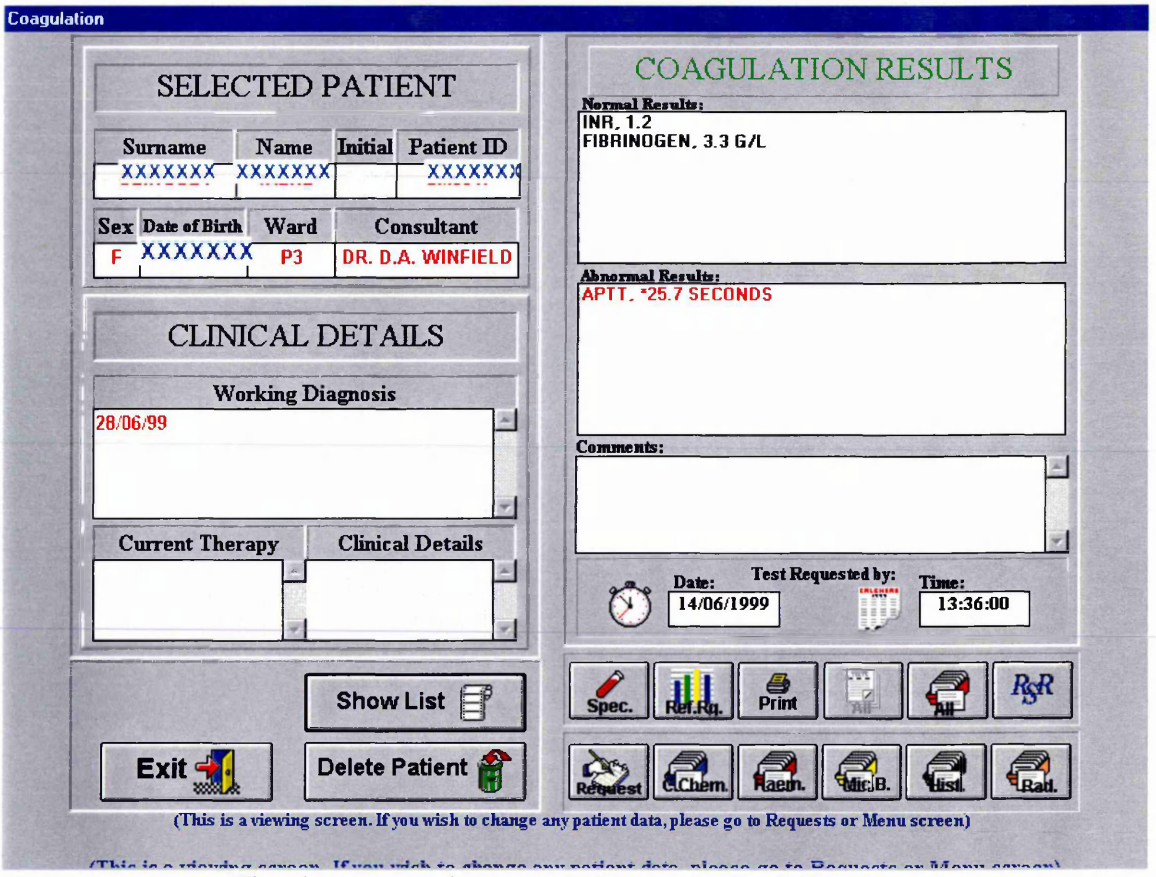

Fig. 6 - Results for coagulation on the RRS System.

Results for a specific patient for Coagulation.

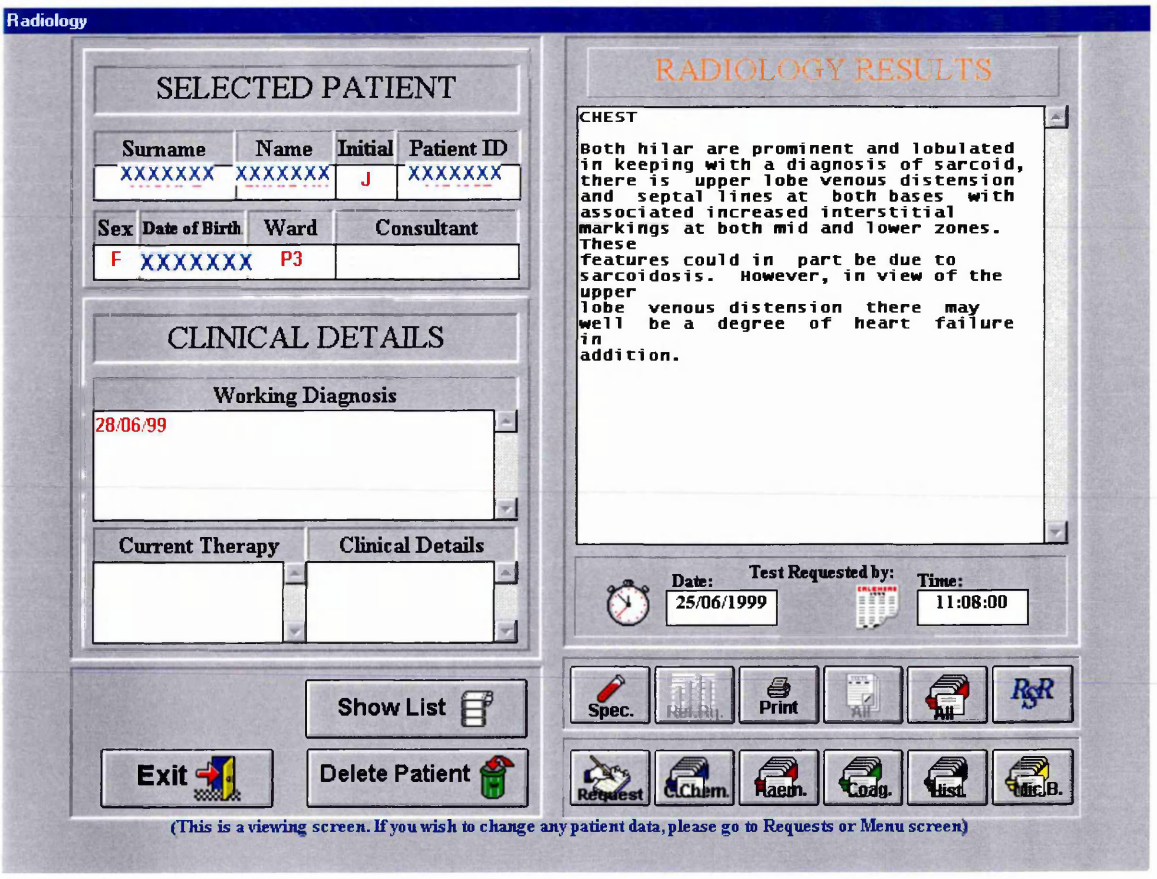

Fig. 6 - Results for radiology on the RRS System.

Results for a specific patient for Radiology.

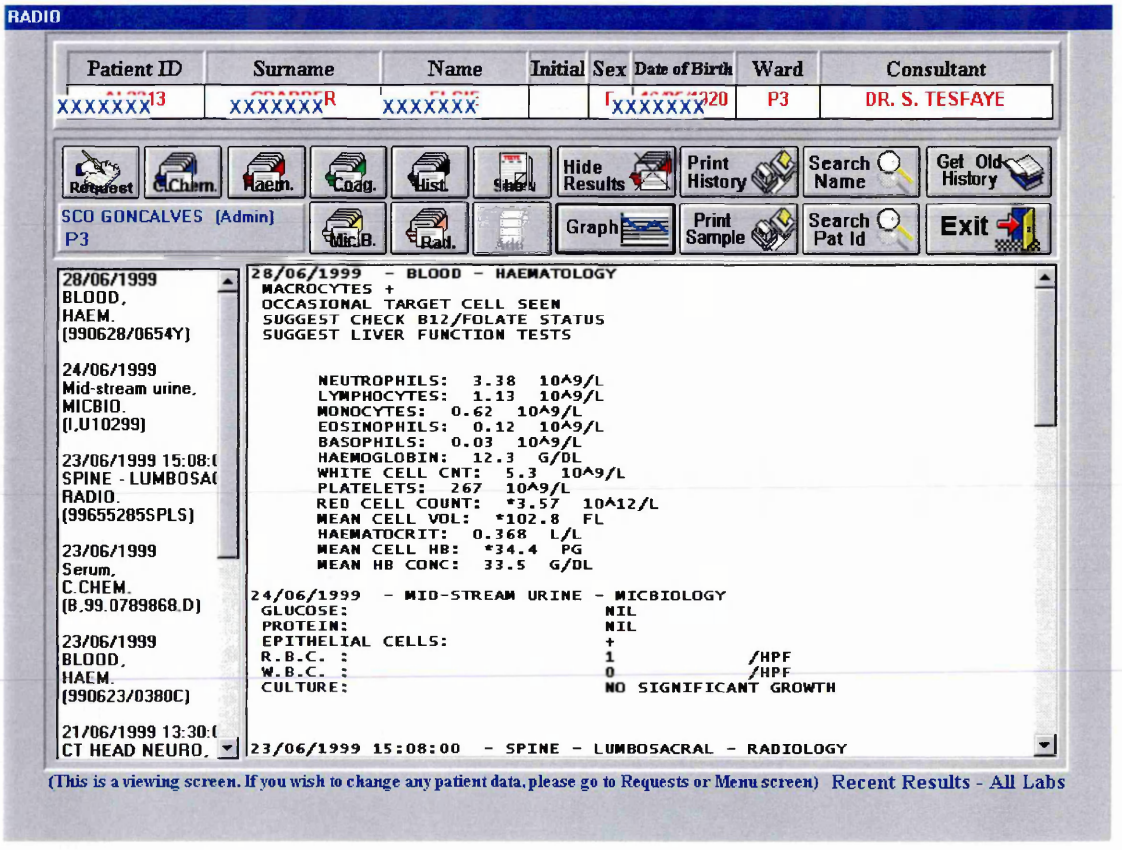

Fig. 7 - Results for all laboratories – recent results.

Results for a specific patient for all laboratories on the same screen. It includes results for the last episode only. Results can then be viewed or printed by individual sample or all at the same time.

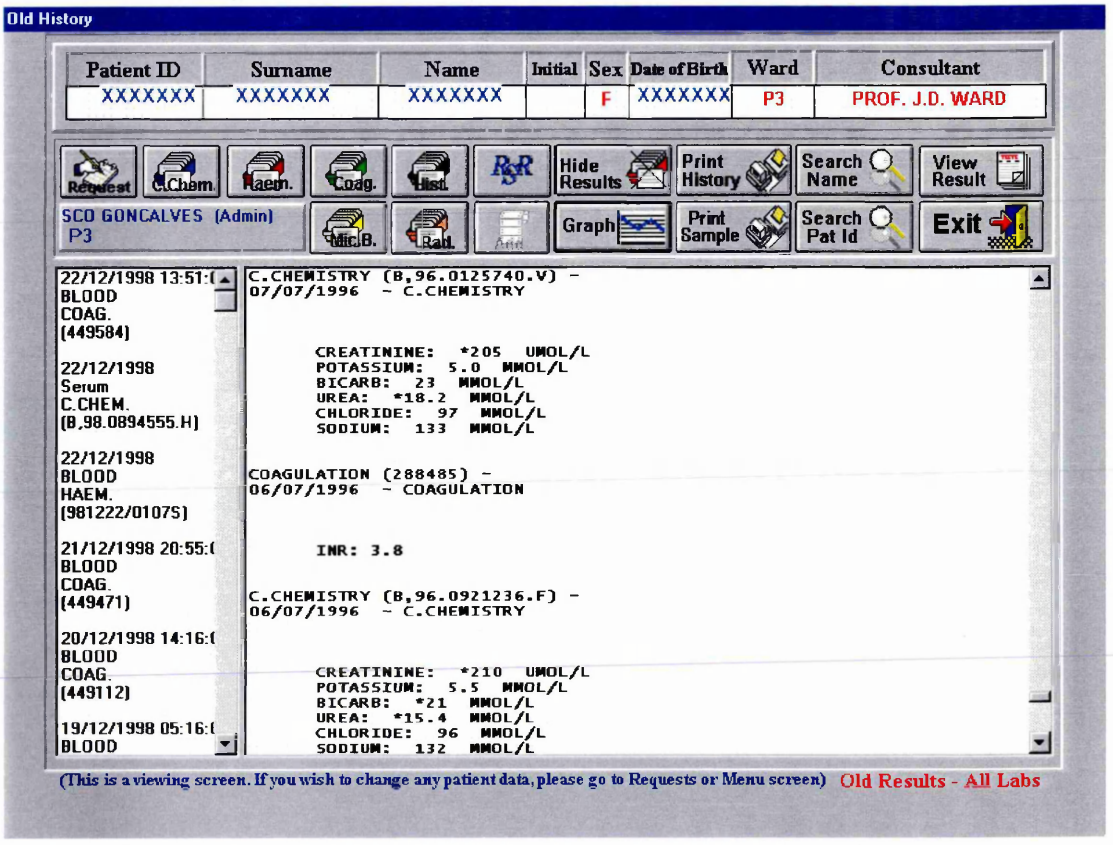

Fig. 8 - Results for all laboratories – old results.

Results for a specific patient for all the laboratories on the same screen, including results from 1995 up to date.

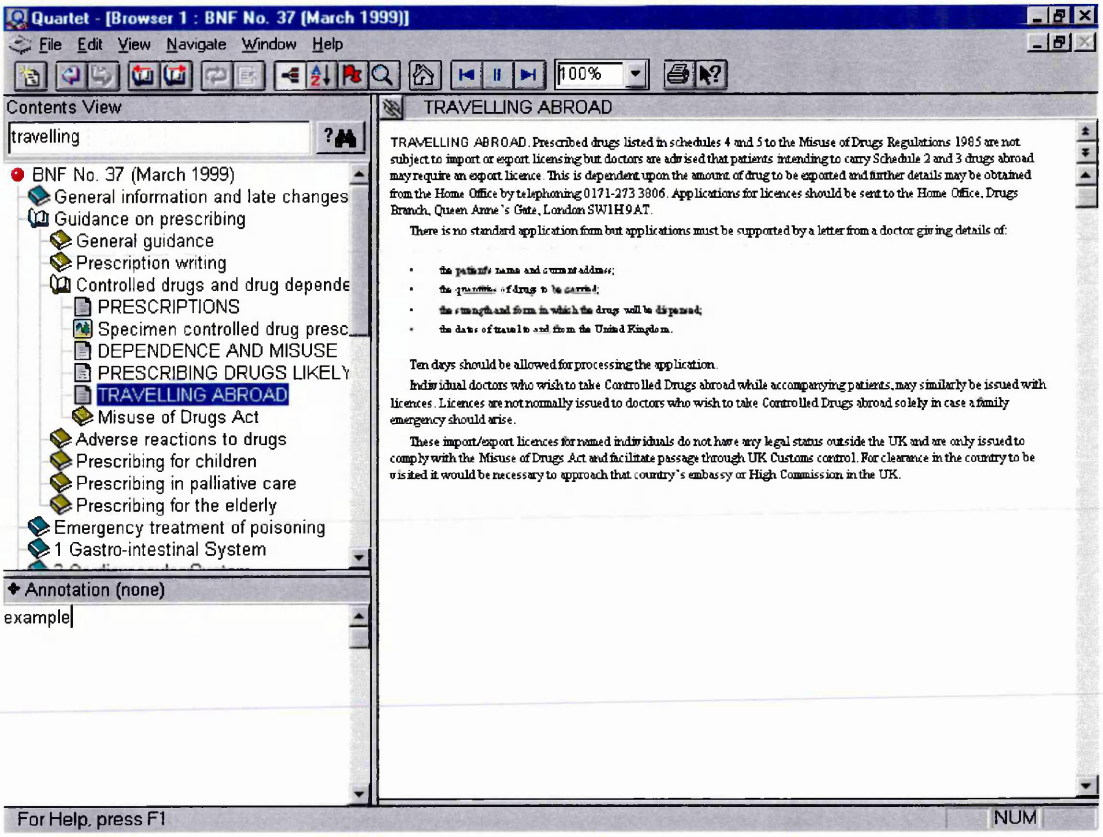

Fig. 9 - eBNF – electronic version of the British National Formulary.

This screen displays the British National Formulary (BNF) for consultation.

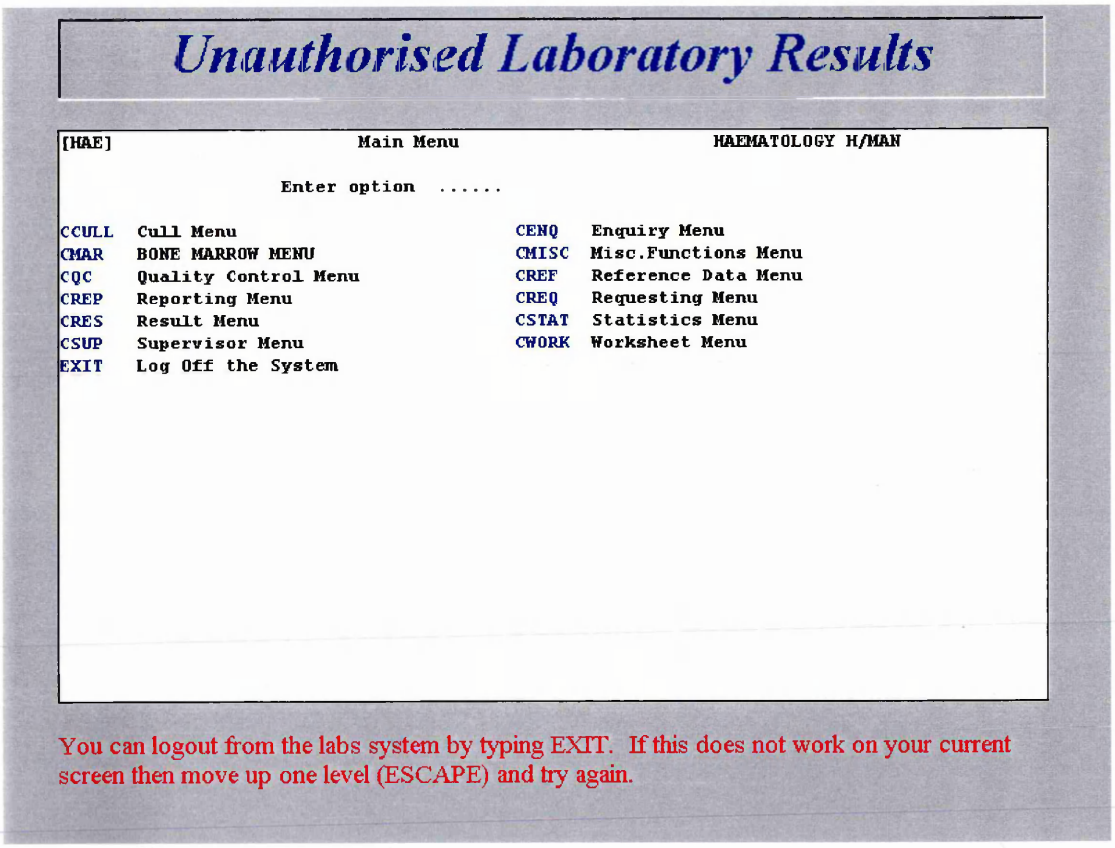

Fig. 10 - Results for all laboratories – old results.

Unauthorised results for the haematology laboratory. This can only be used by haematology authorised users.

17. APPENDIX B

SCREEN SHOTS FROM THE CLINICAL WORKSTATION

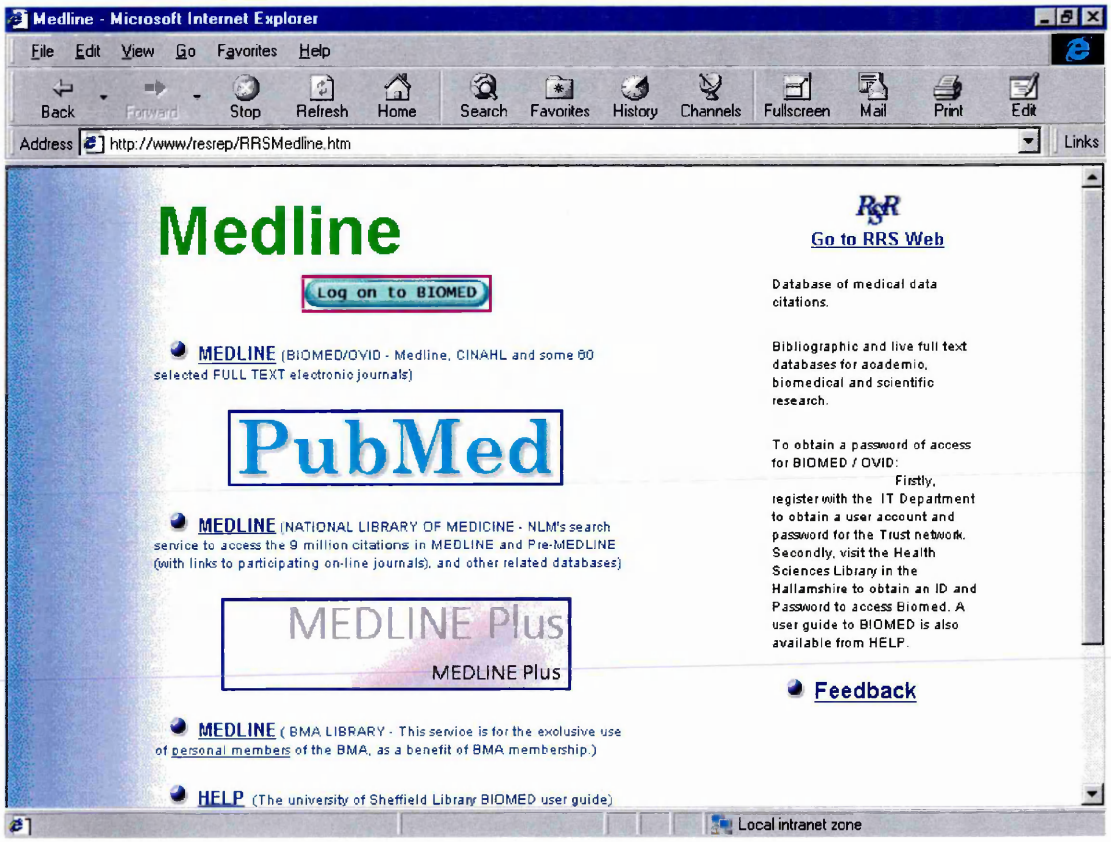

Fig. 1 - Medline.

Access to Medline through different services available. The user can get a password through the Trust to allow access to the BIOMED/OVID.

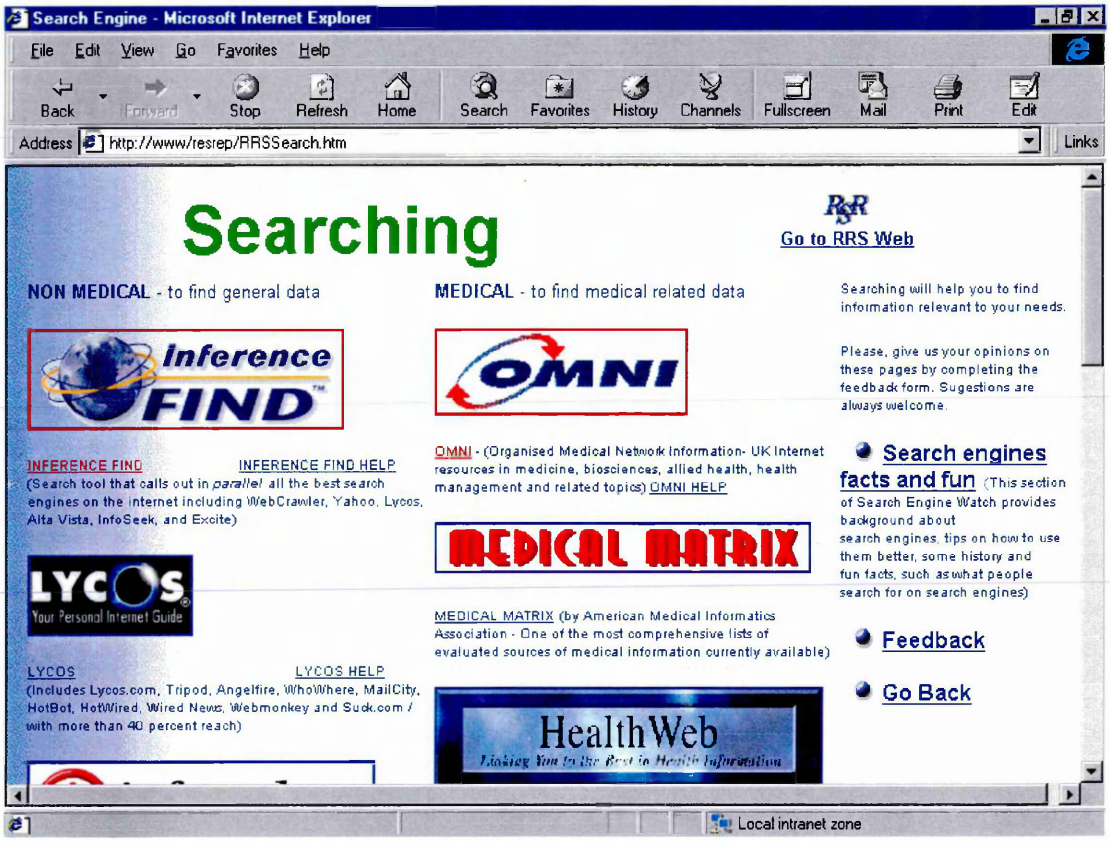

Fig. 2 - Searching.

Access to a selection of search engines available on the Internet. On the left side, non medical search engines and on the right side, medical search engines.

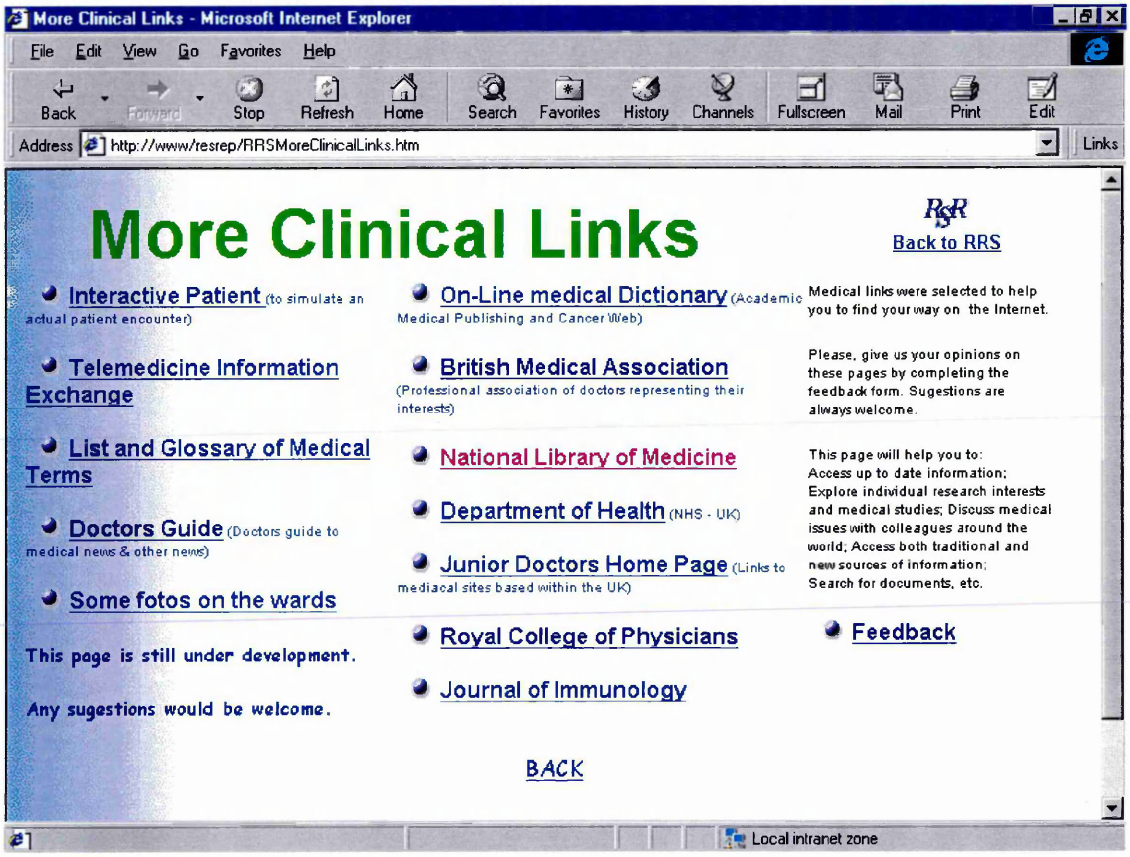

Fig. 3 - More Clinical links links.

More clinical links available on the Clinical Workstation.

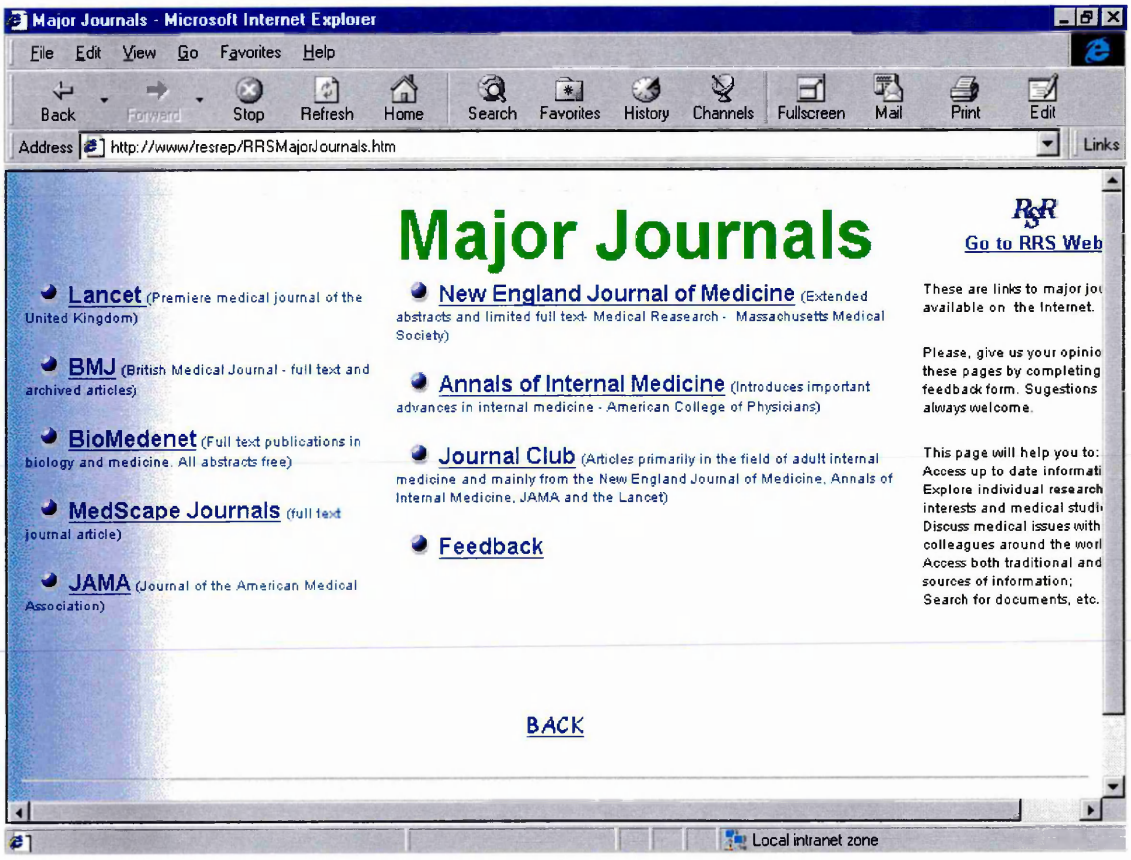

Fig. 4 - General major journals.

Access to major general medical journals with references available on the Internet.

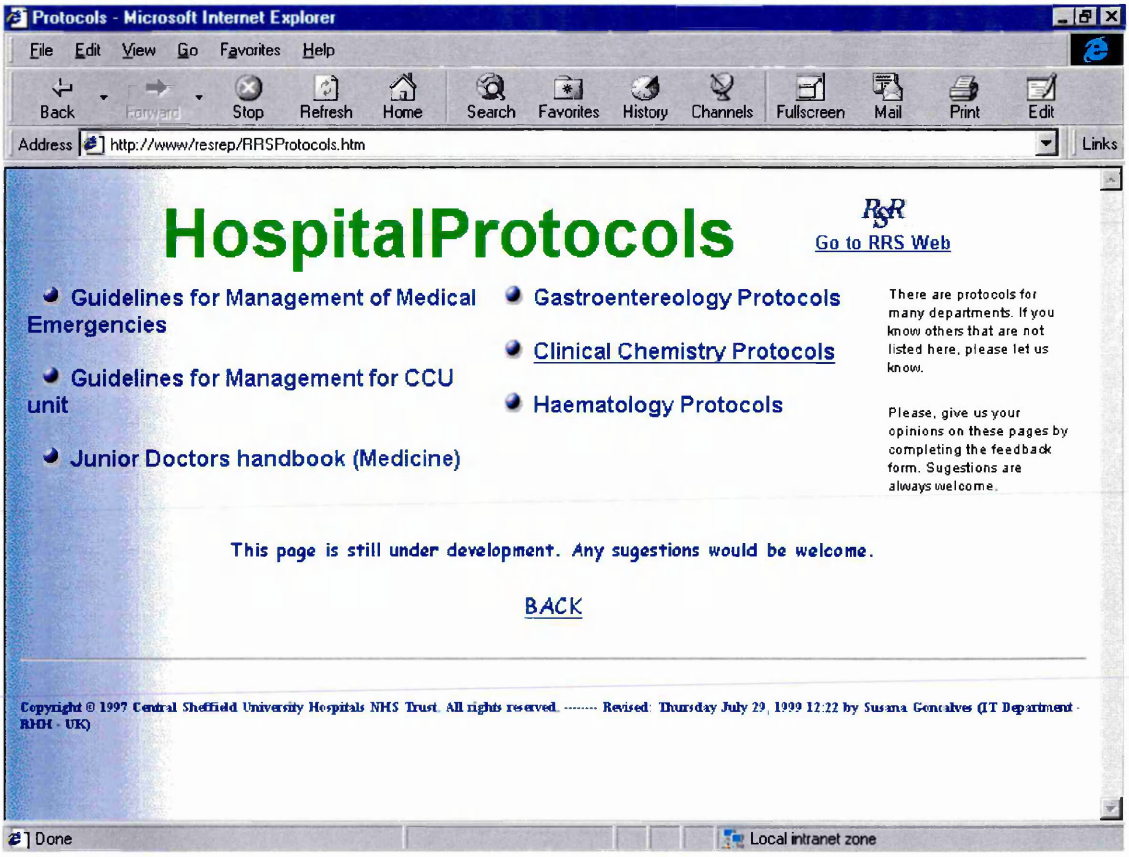

Fig. 5 - Hospital Protocols of care.

Access to internal hospital protocols of care.

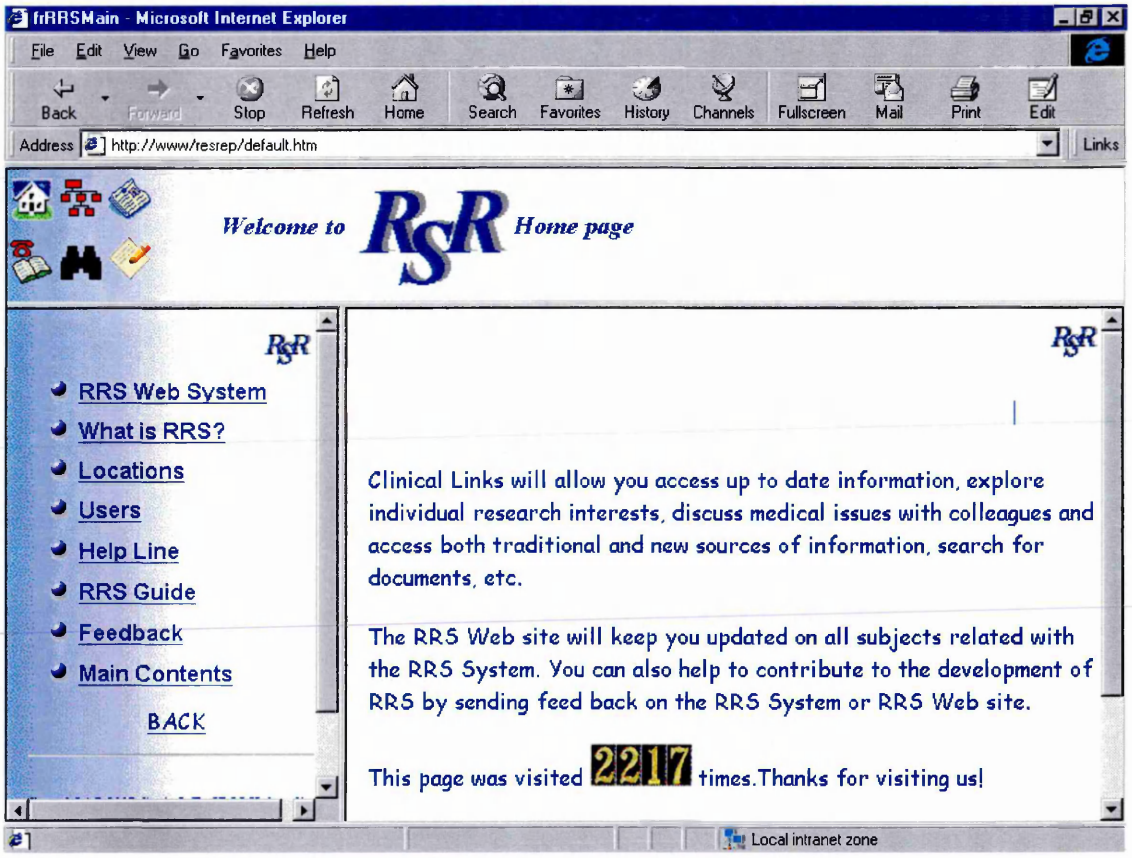

Fig. 6 - RRS web pages.

Access to the RRS Web pages. This contains a system guide and notification of new features implemented in the system.

Fig. 7 - Some general major journals.

Access to patient search on the Clinical Workstation. Also allows access to the status of the processing of the results from the labs.

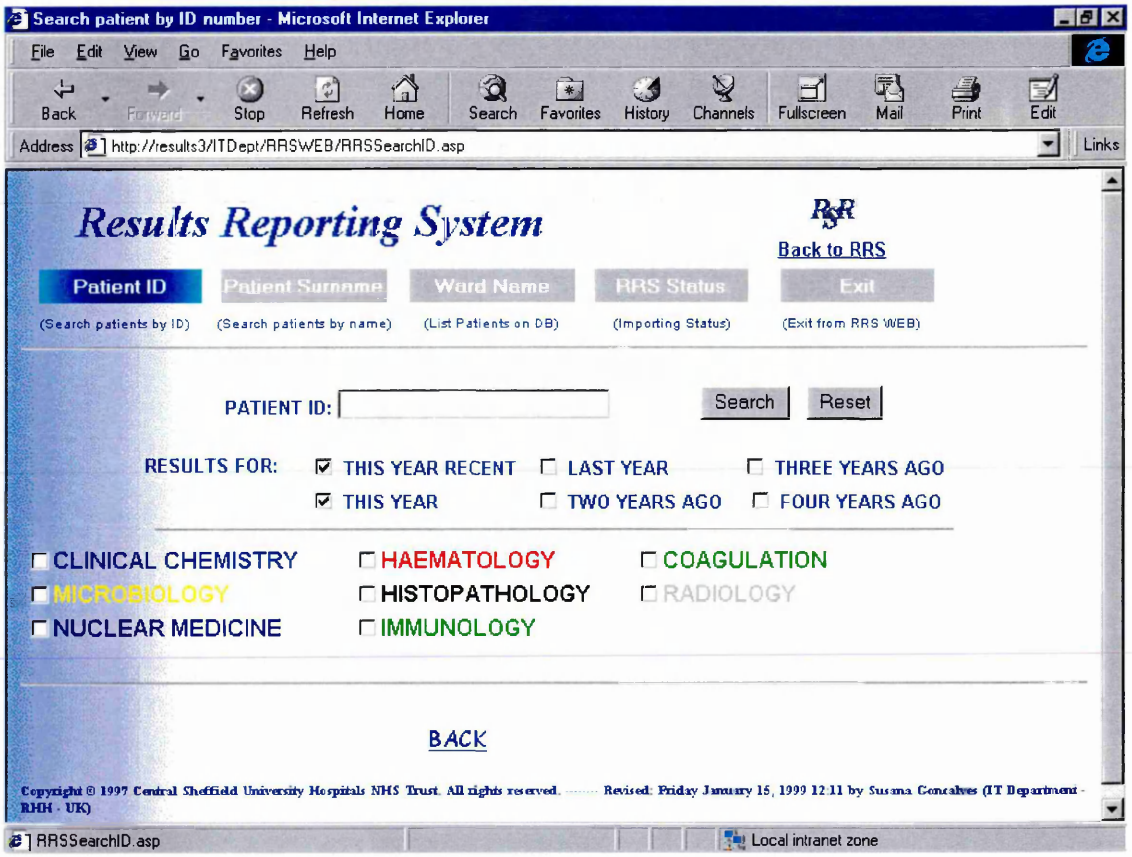

Fig. 8 - Search on patients by hospital number.

Search on patients by hospital number. Can include or exclude information for previous years or a specific search by laboratory.

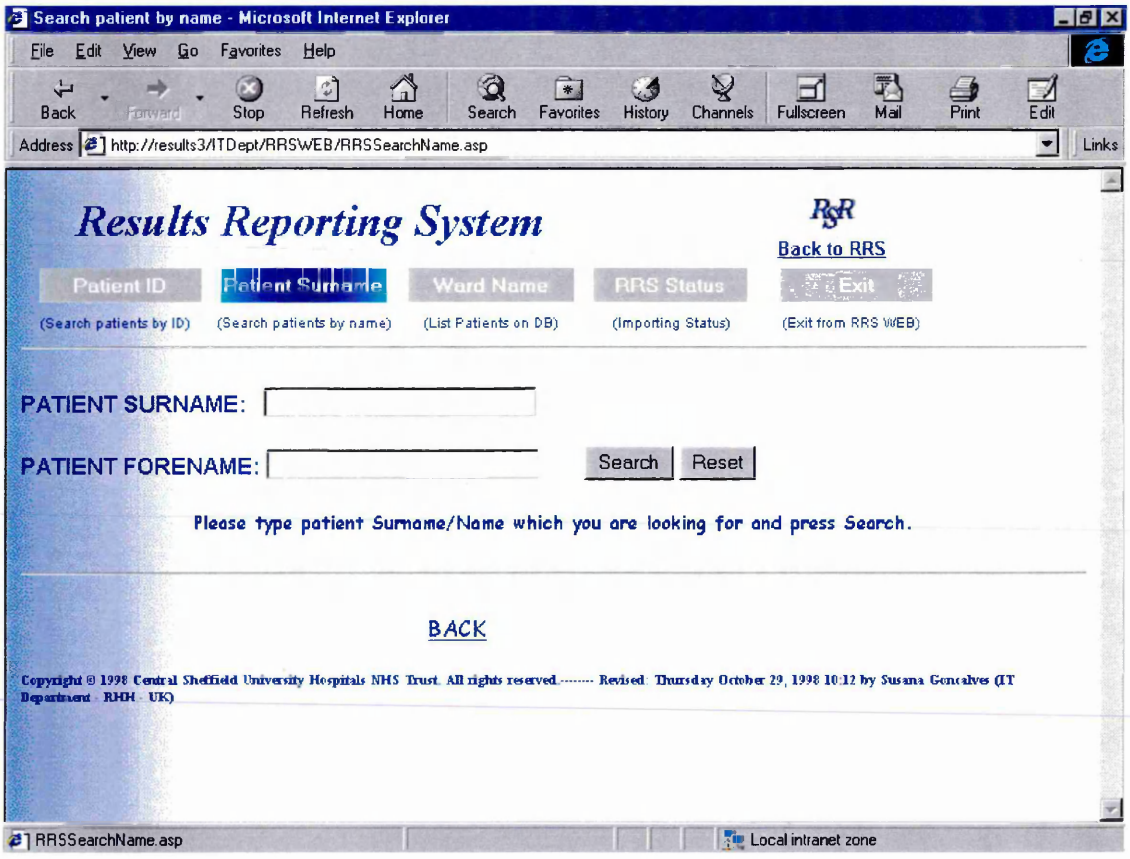

Fig. 9 - Search on patients by surname.

Search on patients by surname and/or forename.

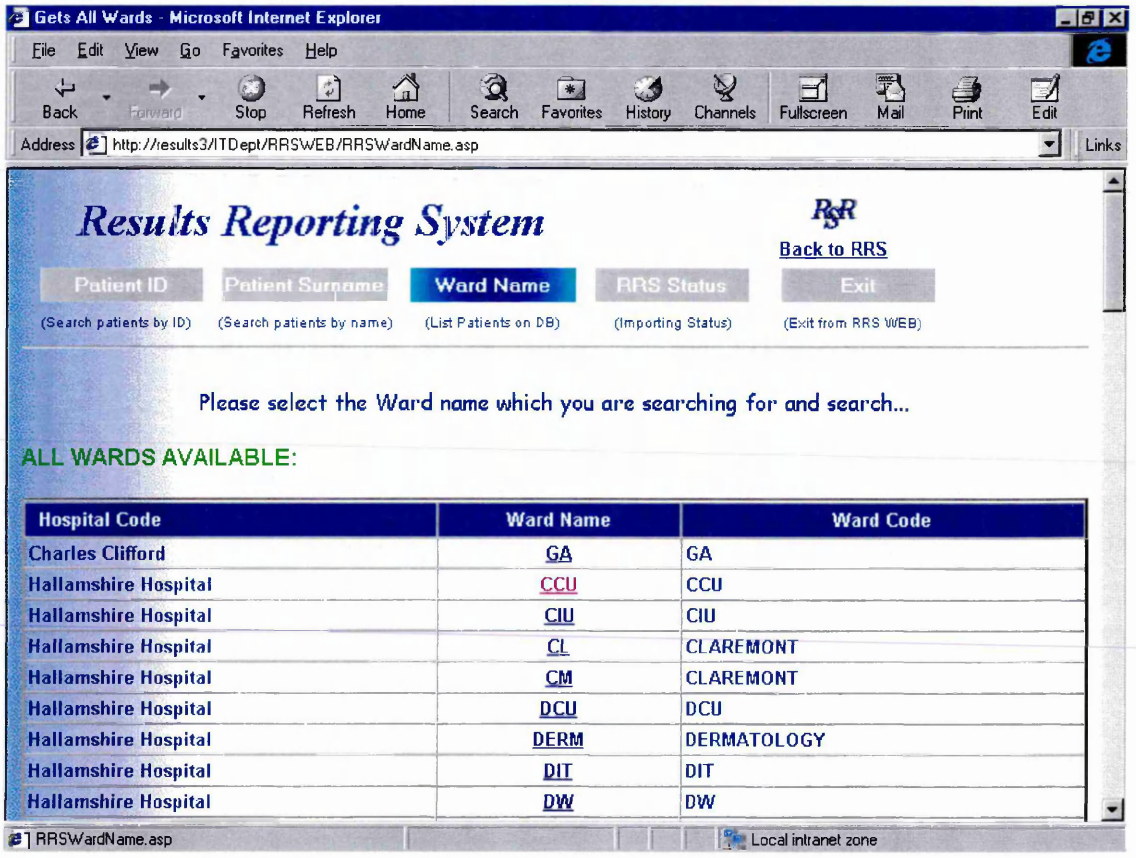

Fig. 10 - Search on patients by ward name.

Search on patients by ward name. A list of patients for the specific ward is displayed.

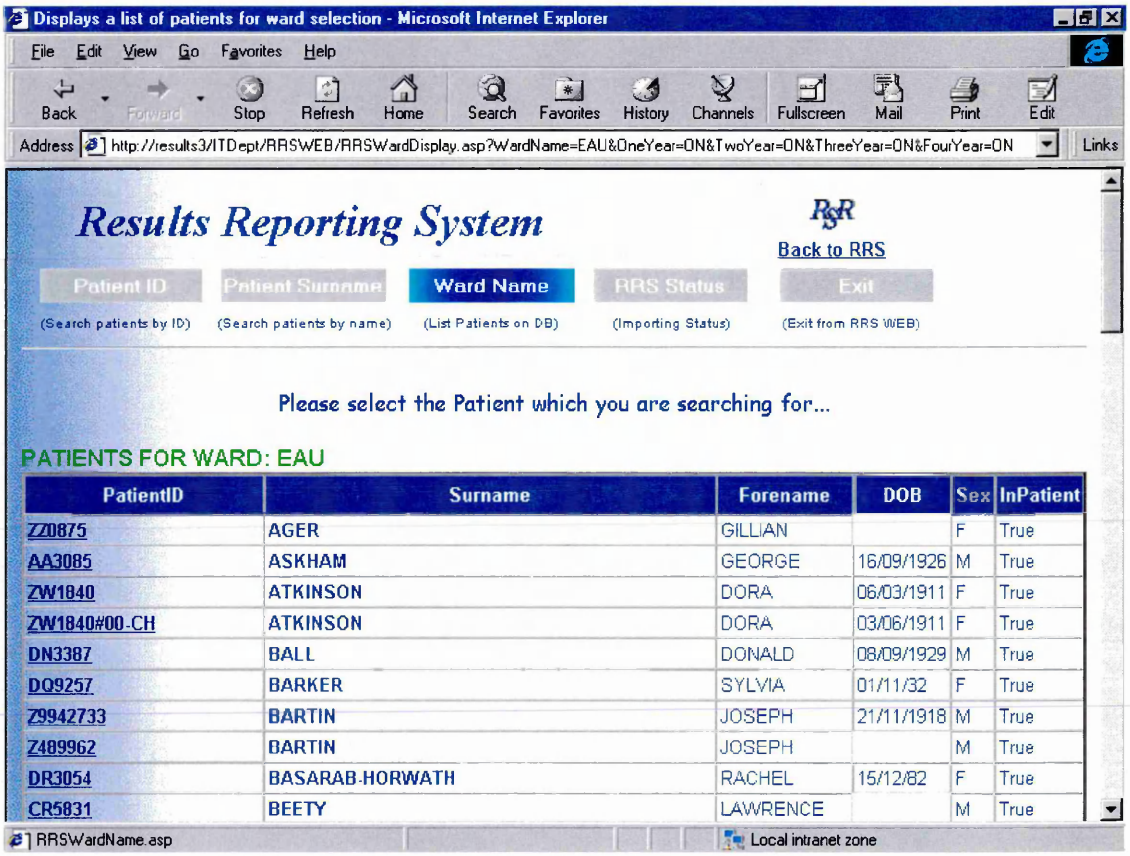

Fig. 11 - list of patients.

List of patients for a specific ward selected.

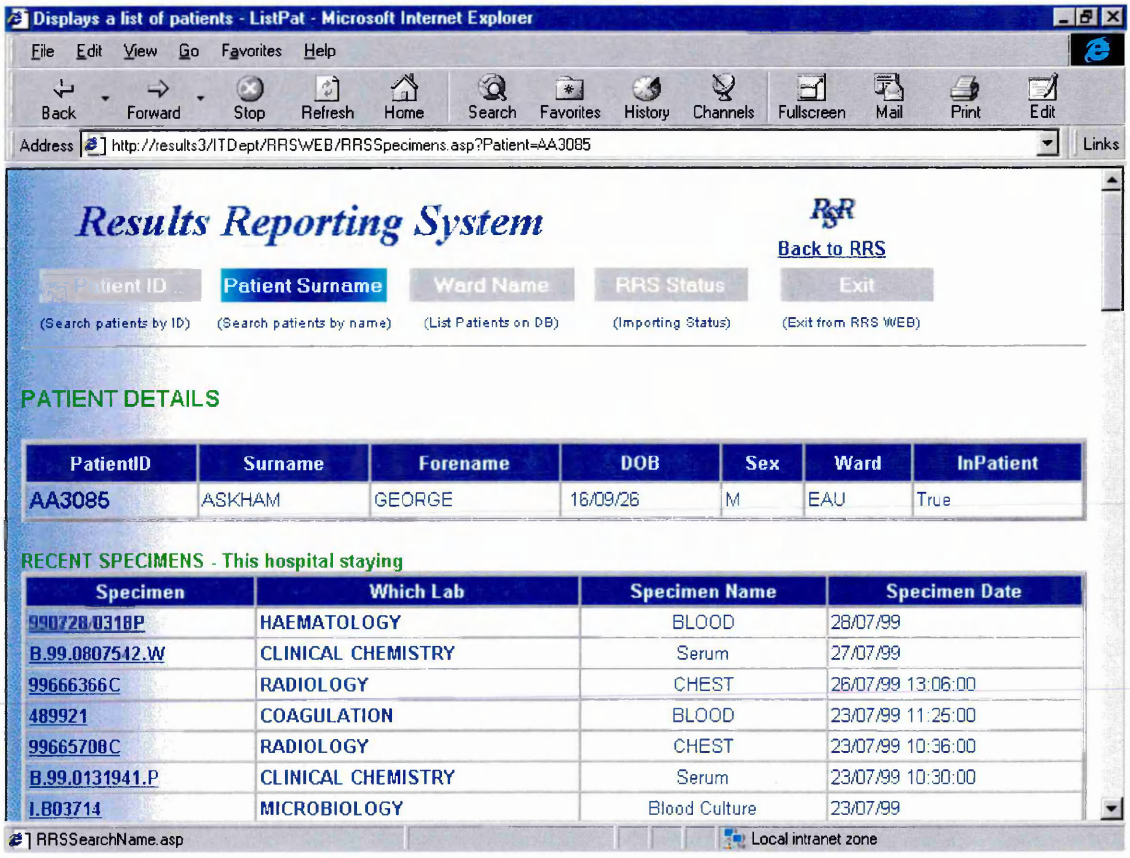

Fig. 12 - List of results.

List of results available for a specific patient.

18. APPENDIX C

USER REQUIREMENTS QUESTIONNAIRE FROM STRUCTURED INTERVIEW

Questionnaire

If you click on the Microsoft Internet Explorer button on the login screen of the Results Reporting system, you will be able to access the Results Reporting Web pages which then gives you access to the hospital internal Intranet. This will contain useful data available for your use. This will be improved, and in future give you access to the Internet. By filling this questionnaire you will help us to find out what else and in what way we could improve these facilities to help you more in your daily tasks...
(An Intranet is an internal network using Internet technology.)

1. Have you ever used the Internet or any other Intranet?	YES NO

After using the Internet Explorer in the available sites...

2. Do you find difficult to go from one Web page to another?	YES NO

3. Are some of the data available at the moment useful for your daily routines?(YES/NO) ☐
(If YES which data? - tick any)

RRS	☐	Labs	☐
Pharmacy	☐	Anaesthetics	☐
CSUH	☐	Other _____	

4. Are you going to use this facility if we increase the data availability through this source and would you feel this is an appropriate media to use?	YES NO

5. Do you think that will improve treatment delivery if you will be able to access a lot of medical information on your ward?	YES NO

Use of existing sources of information...

6. Assess the value of the following information in your routine treatment of patients...
Scale: Not valuable 1 2 3 4 5 *Very valuable*

Individual Patient

- Patient medical record file 1 2 3 4 5
- Clinical information from RRS 1 2 3 4 5
- Clinical advice from senior medical staff 1 2 3 4 5

Reference

- Medical text books 1 2 3 4 5
- Journals 1 2 3 4 5
- Drugs reference 1 2 3 4 5
- Protocols for care 1 2 3 4 5
- Clinical studies 1 2 3 4 5
- Internal audit reviews 1 2 3 4 5

7. When evaluating the clinical state of a patient or planning their care, what sources of information do you use for guidance? (Please tick any)

Ask other staff (YES/NO) ☐ If yes, whom... (Other doctors, nurses, etc.)_____

Hospital Protocols	☐
Hospital library	☐
BNF	☐
Buy your own books and carry them with you	☐
Wait to arrive at home and check it out then	☐
Search for references on MEDLINE	☐
Search on the Internet	☐
National Help lines	☐

Other _____

8. Do you find problems with any of the following when trying to get data to support clinical decision making? (Please tick any...)

Finding relevant data	☐
Knowing where to look for data	☐
The time required to find the data	☐

Other _____

Data availability on the Intranet...

9. Can you please suggest any other information sources which if they were available on the CSUH net would support you in the clinical management of patients?(eg. Medline, BNF, Protocols, etc.)_____

_____

_____

_____

_____

10. Your personal details and how could we get in touch with you...

Surname_____

Forename(s)_____ Title(e.g. HO, REG)_____

Age (Please tick one...):

Less than 25 ☐ Between 25-35 ☐ Between 35-45 ☐ More than 45 ☐

Bleep or extension number _____ Ward name (e.g. P1)_____

Working in RHH since _____until _____(Month and year)

Years of clinical experience _____

11. How many years have you got of experience with computing _____

Existing use of Internet

More than once a week	☐
More than once a month	☐
Hardly ever	☐
Never	☐

12. If you wish you to make any useful comments please use the space below: _____

Thanks for your collaboration!

(November 1997 - Susana Goncalves - IT Department - Bleep 485)

19. APPENDIX D

EVALUATION QUESTIONNAIRE

Questionnaire

1. As a starting point, we ask you to identify a problem over the last week or two, for which you had to look up some references. In what subject area were you looking for data (e.g. Surgery/ Medicine)?

_____

2. Where did you look for data?

Library ☐
Internet ☐
Books at home ☐
Other(Specify) _____

3. How long did it take you to find the required data?

1 hour ☐
1 to 3 hours ☐
More than 3 hours ☐

4. What was the primary purpose in looking for the data?

Confirm Diagnosis YES ☐ If yes After Treatment ☐ Before Treatment ☐

NO ☐

Treatment Options YES ☐ If yes After Treatment ☐ Before Treatment ☐

NO ☐

Personal Interest YES ☐

5. What did triggered the need for looking for that data?

Clinical Investigation ☐ Laboratory Investigation ☐ Ward Round ☐

Post Graduate lecture ☐ Clinical Concern ☐

6. What was the basis of this search?

Diseases ☐ Treatment ☐ Drugs ☐ Keywords ☐

Unit / Centre ☐ Specialty ☐ Complications(adverse drug reaction) ☐

Looking on the Internet via the developed Web pages.

7. Will you use (or have you been already using) some of the sites available via CSUH Internet Links? (Please tick any)

Search Engines YES ☐ NO ☐

General Medical Sites YES ☐ NO ☐ Continues...

Speciality Specific Links	YES ☐	NO ☐
Medline	YES ☐	NO ☐
BNF	YES ☐	NO ☐
Journals	YES ☐	NO ☐
RRS Web Version	YES ☐	NO ☐
Other sites in general	E.g._____	

6. How would you classify in general the presented sites?
Please Rate:

Useful ☐1 ☐2 ☐3 Not very useful.

Too many things ☐1 ☐2 ☐3 Not enough interesting data.

Too little ☐1 ☐2 ☐3 Too much.

Overview of data

7. Is the Information on the Internet easy to search and find? YES ☐ NO ☐

8. Is information via CSUH Intranet easy to search and find? YES ☐ NO ☐

9. Once you select a site is it easy to find information within it? YES ☐ NO ☐

10. Is the information on a format that is easy to use? YES ☐ NO ☐

11. Did the information found fulfil your expectations? YES ☐ NO ☐

12. Was the information found appropriated to resolve the problem you identified? YES ☐ NO ☐

13. Would you find it useful to have an increased number of Clinical links on the CSUH Intranet? YES ☐ NO ☐

14. Do you prefer to search for data on computers instead of in books or a library? YES ☐ NO ☐

15. What do you think of this method of getting data in relation to the old methods?

Worse ☐
Better ☐
Its about the same ☐

If you have used both methods, which one was more effective?
Old method ☐
This method ☐
Its about the same ☐

Which one was quicker?
Old method ☐
This method ☐
Its about the same ☐

16. Your personal details and how we can get in touch with you…

Surname _____
Forename(s) _____ Title(HO, REG, NURSE) _____

Bleep or extension number _____ Ward name (e.g. P1) _____

Working in RHH since _____ until _____ (Month and year)

Years of clinical experience _____

17. If you wish to make any useful comments _____

Thanks for your collaboration!
Feb 1999

(Please return to: Susana Goncalves - IT Department – RHH - Bleep 485)

20. APPENDIX E

PAPER PRESENTED AT SHIMR99

INTEGRATION OF ALL INFORMATION SOURCES IN A CLINICAL ENVIRONMENT

Susana Goncalves[1], Bob Steele[2] , Chris Franks[3], Adrian Wilson [4]

[1]IT Department
Royal Hallamshire Hospital
Glossop Road,
Sheffield, S10 2JF, UK
Susana.Goncalves@csuh-tr.trent.nhs.uk

[2]School of Comp. & Mngmnt. Sciences
Sheffield Hallam University
Pond Street,
Sheffield, S1 1WB, UK
R.Steele@shu.ac.uk

[3]IT Department
Royal Hallamshire Hospital
Glossop Road,
Sheffield, S10 2JF, UK

[4]University of Sheffield
Medical Physics Department
Royal Hallamshire Hospital
Glossop Road,
Sheffield, S10 2JF, UK
Adrian.Wilson@Sheffield.ac.uk

ABSTRACT

If evidence based medicine (EBM) is to become fully integrated with patient care then we believe it essential that reference sources must be readily available at the point of healthcare delivery and be seamlessly integrated with access to the medical record. We have employed a user centred design approach to develop a prototype ward-based clinical workstation, which uses Web technology to provide consistency of both user and data interfaces. Two sources of information are required for our work: the first is an Electronic Patient Record (EPR); the second is the reference material. As a first stage towards a clinical workstation to support EBM, the most commonly required sources of reference material were identified using semi-structured interviews. A first prototype system to evaluate the potential for a workstation to support EBM was constructed by developing a web based interface to the hospital's laboratory Results Reporting System (RRS). Links between this and the most commonly used reference sources identified in the semi-structured interviews were established. An evaluation of this prototype suggested a high acceptability of both the user interface and of the concept of a clinical workstation which allows access to both patient specific and reference data.

1. INTRODUCTION

Evidence based medicine (EBM) is an approach to patient care which ensures that potential advances in health care must be tested and proven to do more good than harm before they are incorporated into medical practice [1]. It promotes the collection, interpretation and integration of patient reported, clinician observed and research-derived evidence. For this information to be used as an integral part of medical practice, regularly updated systematic reviews are essential such as those organised through the Cochrane Collaboration [2]. It has been argued that electronic access to information sources from the health care professional's normal work place is the only feasible way to bring EBM into routine clinical practice where it is used as a framework for determining the care of individual patients [3].

Within the context of clinical decision making using EBM, two sources of information are necessary. Firstly **patient information,** which includes treatment regimes, clinical assessments and the results of laboratory tests on a particular patient. Secondly **reference information**, which is the evidence base on which to justify the care delivered to that patient. We believe that bringing patient and reference data together so that they can be accessed through a single workstation within the hospital

workplace could provide an effective tool to support healthcare delivery using EBM. The concept of the clinical workstation is one that has been used to describe a single workstation which gives access to all clinical information [4]. If this concept is applied to a workstation to support EBM, then both patient specific and reference information must be available through the workstation.

This paper describes work at the Royal Hallamshire Hospital (RHH) in Sheffield, which is an acute 700 bedded teaching hospital within an industrial city. The work aims at integrating access to reference and patient data through a single user interface – a Web browser – as a method of providing direct support for the delivery of EBM. We have employed a user centred iterative approach to the research and in this paper we describe two iterative cycles in which we investigate the user requirements and a first prototype system which has been evaluated in the clinical environment.

2. BACKGROUND

The delivery of care to individual patients in acute hospitals essentially involves repeated cycles of health care professionals assessing the physical, physiological and biochemical state of the patient and then using their professional knowledge and judgement to plan the care of that patient. This process may be broadly defined as 'clinical decision making'. A key element of the clinical decision making process is the collecting and processing of data. These activities have traditionally been centred around paper records. Computer programs designed to collect and process patient data can support health care professionals in their clinical decision making and such systems are commonly referred to as Clinical Decision Support (CDS) systems [5].

If clinical decision making is to be carried out within an EBM framework, then health care professionals not only need access to patient specific data but also need access to reference data, which is used to support the decisions they make. A wide variety of standard reference materials are available including textbooks, journals, drug references and equipment manuals. Other, perhaps less obvious, sources of reference material include national or international protocols of care (e.g. American Association of Anaesthesia), local protocols of care and safety regulations. In addition, a large quantity of medical reference information can also be found on the internet - information which is being continuously extended and updated.

A number of studies have assessed the effect of EBM on clinical decision making, including one by Wood and Wright[6] in which the decisions made by general medical practitioners in the Trent Health Region were analysed. The results showed that patient management was altered in two-thirds of the cases when reference information was incorporated into the clinical decision making process.

In this study we have adopted an iterative user centred design approach. The key elements of this are repeated cycles of prototyping and evaluation. The evaluation, from a user's perspective, needs to measure attitudes and satisfaction with the prototype system. Although this is central to the methodology used, it is recognised that it is difficult to do formally [7]. The key tools available are structured interviews and questionnaires. Whilst personal interviews give a higher response rate, a direct interaction with the subject, and the potential for clarifying both the meaning of

questions and responses, questionnaires have the potential for obtaining a larger number of responses [8].

At the RHH the Results Reporting System (RRS) is one of the systems containing patient information developed to run in the ward environment. It is widely used by the medical staff and is designed to enable staff to send clinical laboratory test requests and receive laboratory test results. The system is an important source of data to support the clinical decision making process and it therefore forms the focus for patient data in the work reported in this paper.

In this paper we report on 2 development cycles: the aim of the first was to determine the user requirements and the aim of the second to evaluate a first prototype workstation which supported access to both reference and patient specific information.

3. DETERMINING THE USER REQUIREMENTS

3.1 Method

A key property of the internet and Web technologies is that they integrate data from different sources and different places into a standardised format that can be accessed through a standardised user interface. Clearly, such an approach potentially offers an appropriate platform for integrating reference material with patient specific clinical details. If it is to be successful in the clinical environment then the key questions to be asked are:

- What are the most important sources of information?
- Do Web browsers provide an appropriate interface for accessing both reference and patient specific data within the clinical environment?

In order to address these questions, the opinions of health care professionals within the RHH were sought. The methods employed included observation of use, semi-structured interviews, questionnaires and a feedback form available on the system. The semi-structured interview was the most important of these and was based around an evaluation of the clinical IT systems within the ward environment. Prior to the semi-structured interviews, the RRS was modified so that access to the internet was provided from its user interface. This was used within the semi-structured interview to evaluate the use of internet technology for obtaining reference information to support clinical decision making and the acceptability of a web-browser interface. As part of the semi-structured interview a questionnaire was completed which identified the most commonly used sources of reference information to support clinical decision making and problems with accessing them. Finally, the questionnaire identified how much experience the interviewees had of using the internet and their awareness of the information available.

3.2 Results

Among the medical staff of the RHH, 40 doctors were approached to take part in the evaluation process. All the 40 doctors contacted were co-operative and willing to participate in the experiment. They varied in their professional experience with almost equal numbers of House Officers, Senior House Officers, Registrars and Specialist Registrars.

The 40 doctors interviewed all felt that an increased availability of reference material on the ward would improve patient care. From the clinical systems currently available on the wards of the RHH, 90% (36 out of 40) of those interviewed routinely used the RRS.

Part of the questionnaire within the semi-structured interviews assessed the potential for using a web-browser interface to access both clinical and reference data. 22 of the 40 doctors used in the trial had previous internet experience. No difference was found in the results for questions relating to the user interface and commonly used sources of both reference and clinical information between respondents on the basis of previous internet experience. Therefore results are reported for the total group of 40 subjects.

The questionnaire also explored problems of obtaining data to support clinical decision making. Of the 40 doctors, 25 identified a problem with finding relevant information and 24 identified a problem of knowing which reference sources would provide relevant information. In addition, 34 of the 40 doctors had a problem with the time required to search for information to support clinical decision making. Doctors were asked to assess the importance of commonly used sources of both reference and patient specific information using a 5 point visual analogue scale. The results are shown in Table I. These show that an almost equal importance was attached to all the sources identified. In addition, the participants were asked to identify specific texts and other information sources which they commonly used. Twenty-eight different sources of information were identified and these were ranked in order of frequency of citation (Table II). This showed that the BNF (British National Formulary of drugs), Medline, protocols of care and the Oxford Handbook of Medicine were the most commonly used sources of information. All the doctors interviewed stated that they consulted colleagues when they required further information on evaluating the state of a patient or planning their care.

3.3 Discussion

The analysis of the results from the semi-structured interviews provided the inputs to the next iterative cycle of the user centred design methodology. These showed that if reference information was to be provided through workstations on the wards, then the following must be provided:

- A Selection of one or more textbooks in general use with rapid access to searching facilities based on subject.
- A link to an online BNF which could be quickly accessed.
- Patient care and investigation protocols in a form, which could be made patient specific.
- Medline access with links so that the full journal articles could also be accessed.

- Direct access to the major medical journals, particularly the most recent editions

Part of the semi-structured interview evaluated the ease with which clinical users could access Web based information. The results from this suggested that a Web browser interface could be successfully used on the wards.

4. A PROTOTYPE CLINICAL WORKSTATION

4.1 Method

The results from identifying the user requirements (Section 3.2) formed the inputs to the design of a prototype clinical workstation which was implemented and then evaluated on the wards of the Royal Hallamshire Hospital. A web-enabled user interface to the RRS was developed so that there was a unified look and feel between the patient specific and reference data (Figure 1). The top-level navigation screen for the workstation supported links to both the RRS and the most important sources of reference data identified from the semi-structured interviews (Figure 2).

The system using the interface shown in Figures 1 and 2 was implemented and deployed on the wards of the RHH. Data for some of the links provided came from a local intranet server (e.g. links to the BNF and the drug information system) whilst others were links to servers on the internet. Links to the internet were achieved through a firewall to ensure the security of patient data. Access to reference material was organised using a two part hierarchy with the first level being the medical specialty (Figure 3) and the second level being the key information sources within that specialty (Figure 4). The aim was to provide navigation tools that were broad rather than deep to minimise the risk of users becoming lost in a complex series of menus. It should be noticed that the links are not only to specific sources of information (e.g. specific journals) but also to facilities which can identify sources of information (e.g. Medline, Bids etc.). This was seen as a particularly important feature given the difficulties identified in the semi-structured interviews with finding sources of reference material.

On completion of these developments, an evaluation of the functionality provided was carried out. The objective of the implementation was to provide facilities for a large number of clinical users within the ward environment. Therefore as a first stage in the evaluation, a questionnaire was used to assess user satisfaction with the facilities provided. Doctors who took part in the evaluation were asked to complete a questionnaire within the context of a recent clinical problem where they needed reference information. The questionnaire sought information on the context in which the need for data was generated (e.g. a ward round), the clinical reasons for which the data was required and the reference sources used. Details of the questions are included in Tables III and IV, where the results are also presented.

4.2 Results

16 senior medical staff from the wards of the Royal Hallamshire Hospital completed the questionnaires. Of the 16 respondents, 1 was from general surgery, 2 from general medicine, 4 from anaesthesia, 5 from ophthalmology, 1 from clinical

neurophysiology, 1 from the diabetic centre, 1 from infectious diseases and finally 1 from Neurology. The results of the questionnaire are given in Tables III and IV.

4.3 Discussion

The results from the questionnaire (Table III) showed that the majority of respondents used the inter/intranet facilities provided through the prototype system as a source of reference data. To a certain extent, the importance of reference information as a routine part of a senior clinician's working routine can be seen from the fact that about a third (5 out of 16) spent between 1 and 3 hours searching for it. The user requirements identified that searching for reference information was a significant problem. The results of this questionnaire confirm this finding, since all of the respondents cited Medline as one of the facilities in the prototype system they used and the majority also used one of the medical search engines. Two conclusions can be drawn from these findings. Firstly, any tools which can significantly reduce the time spent searching for reference information must improve working efficiency; and secondly, if EBM is to play a significant role in routine patient care then efficient tools to search for reference information must be developed. This view is further supported by the majority of respondents citing 'personal interest or research' as one of the purposes for obtaining reference data whilst 'clinical concern' and/or a 'clinical investigation' were the most commonly cited contexts in which the search was performed. These responses suggest that the use of the reference data is currently part of an ongoing continuous professional development activity rather than one which is integrated into the clinical decision making process. Clearly, improving the search facilities must be a priority in the next prototype. The user requirements identified the BNF drug reference as one of the key sources of reference information. However, only just over half the respondents (7 out of 16) used the on-line version provided in the prototype system. In view of the importance of the BNF in clinical decision making, this finding requires further investigation.

The questionnaire not only aimed at identifying what facilities from the prototype system were used, but also at subjectively evaluating its value and acceptance. The majority of the respondents (11/16) used the prototype system as a source of reference information. One problem with intra/internet resources is that it is possible to make a large quantity of information available but that in doing so finding specific information becomes very difficult. The majority of respondents felt that the quantity of data provided through the prototype was appropriate to their needs (14/16). Perhaps more importantly, the majority of respondents (13/16) felt that the quality of data was satisfactory. This is particularly important if the information retrieved is to be used for clinical decision making.

The tools provided for searching the internet for specific information were generally found to be satisfactory (11/16), however the questionnaire identified more general problems of accessing information through the system since only 9 out of 16 were satisfied with the tools provided. Of the remaining 7 respondents, 3 made no reply which was identified in the analysis with a 'no' response. The remaining 12 responses were partitioned on whether the respondent had familiarity with the RRS. 9 routinely used the RRS and of these 7 expressed satisfaction in the way reference information was accessed through the prototype system. This suggests that familiarity of use may play an important factor in acceptance.

5. DISCUSSION

In this paper we have described the first two cycles of an iterative prototype development of a clinical workstation which aims to integrate patient and reference information to support clinical decision making within the framework of evidence based medicine. The first cycle identified the user requirements whilst the second constructed and evaluated a prototype within the clinical environment.

The results of the questionnaire, which evaluated the prototype system, showed that the majority of the doctors who took part were satisfied with both the quantity and quality of information that was provided through the prototype system. They judged it to be a better, more effective and quicker method of accessing reference data.

One key finding in the user requirements was the value of inter-professional communication in evaluating different therapeutic and investigation regimes. Whilst not part of the current project, it is clear that future developments would have to include facilities for collaborative working amongst health care professionals. A simple way of achieving this initially would be internal through the use of newsgroups which would allow a detailed set of user requirements for the functionality to be determined.

The need for an effective method of searching for reference material was clearly identified in the user requirements. However, this need was not completely satisfied by the functionality provided in the prototype system. If the workstation is to actively support clinical decision making within an EBM framework, then reference data must be directly accessed from the patient data through some form of automatically generated hypertext link. The results of the evaluation of the prototype clinical workstation suggest that a keyword search based on diseases and treatments would be a high priority for the next prototype. Single terms could be used to access locally defined protocols of care [9]. However, complex combinations of terms with automatic contextual reasoning would be necessary to use such an approach for searching large information resources such as Medline if a small number of highly relevant information sources were to be identified.

The BNF drug reference was identified in the user requirement as one of the key sources of reference material for clinical decision making, however, less than half of the doctors who took part in the evaluation used it. This surprising result requires further investigation. One possibility is that the information is often required as part of prescribing a drug. Since the drug prescription cards are currently paper records, it could be that the information needs to be available in the same physical location as the drug records are stored. A partial task analysis could be of value in investigating this finding further.

In using internet sources to support clinical decision making it is essential that due regard is taken of the quality of the information provided. There is no automatic requirement for peer review as there is in the quality medical journals. Within this study, explicit navigation paths were only provided to 'approved' medical sites where the information provided had been peer reviewed. There is however, nothing to stop

users accessing any material on the internet. A logical extension of integrating EBM into clinical decision making is that the sources used to support a particular decision ought to be referenced as part of the patient record. Clearly, this will not occur unless reference data is integrated with an electronic patient record. If this integration is to occur, then it offers the potential for rapidly producing a large volume of reference material based on clinical experience which could be systematically reviewed in a similar manner to that used in the Cochrane Collaboration and then rapidly disseminated. This would make clinical decision making within an EBM framework more viable since the focus for reference information would shift from academic studies to clinical practice.

6. REFERENCES

[1] "The Medical Literature as a Resource for Evidence Based Care", K. A. McKibbon, N. Wilczynski, R. S. Hayward, C. J. Walker-Dilks, R.B. Haynes, Health Information Research Unit, June 1996,

[2] "The Cochrane Collaboration - Preparing, maintaining and promoting the accessibility of systematic reviews of the effects of health care", The Cochrane Collaboration 1999, http://wwwsom.fmc.flinders.edu.au/fusa/cochrane/cochrane/cc-broch.htm

[3] "Getting the Evidence" – Arnel de Serra, Health Service Journal, 28 May 1998

[4] "Integrated Clinical Workstation: Project User Requirements (Acute Hospital)", NHS Centre for Coding and Classification, Woodgate, Loughborough, UK, 1993.

[5] "Computer programs to support medical decision making" - Edward H. Shortlife - JAMA - Vol. 258, no 1, July 1987

[6] "The impact of information on Clinical Decision making by general medical practitioners", F. Wood, P. Wright, 1996, http://www.shef.ac.uk/uni/academic/I-M/lecturer/paper11.html.

[7] "Evaluating medical expert systems: What to test and how?" - J. Wyatt and D. Spiegelhalter, Medical Informatics, Vol. 15, no 3 - 1990

[8] "Information seeking: assessing and anticipating user needs" - C.Chen and P Hernon, New York/Neal Shuman, 1882.

[9] "SGML for Medical Rescords – The Oswestry Pilot Project" – Andrew Roberts FRCS DM, Autumm, 1997, http://www.keele.ac.uk/depts/rjah/sgml/sgmlmain.htm.

Figure 1. An example screen from the web-enabled user interface to the hospital's Results Reporting System showing clinical chemistry results used in clinical decision making.

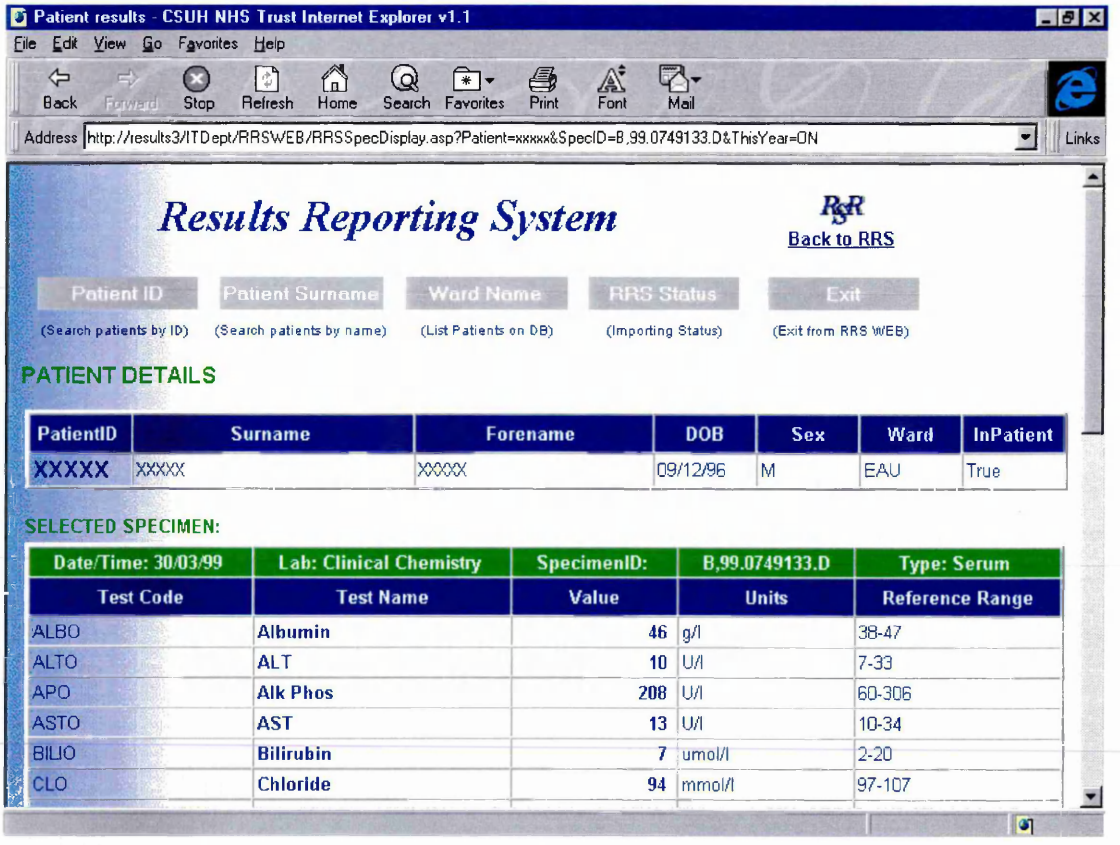

Figure 2. Top level navigation screen for the prototype workstation giving access to both patient and reference information. The 'Specialty Specific Links' gives access to the screen shown in figure 3.

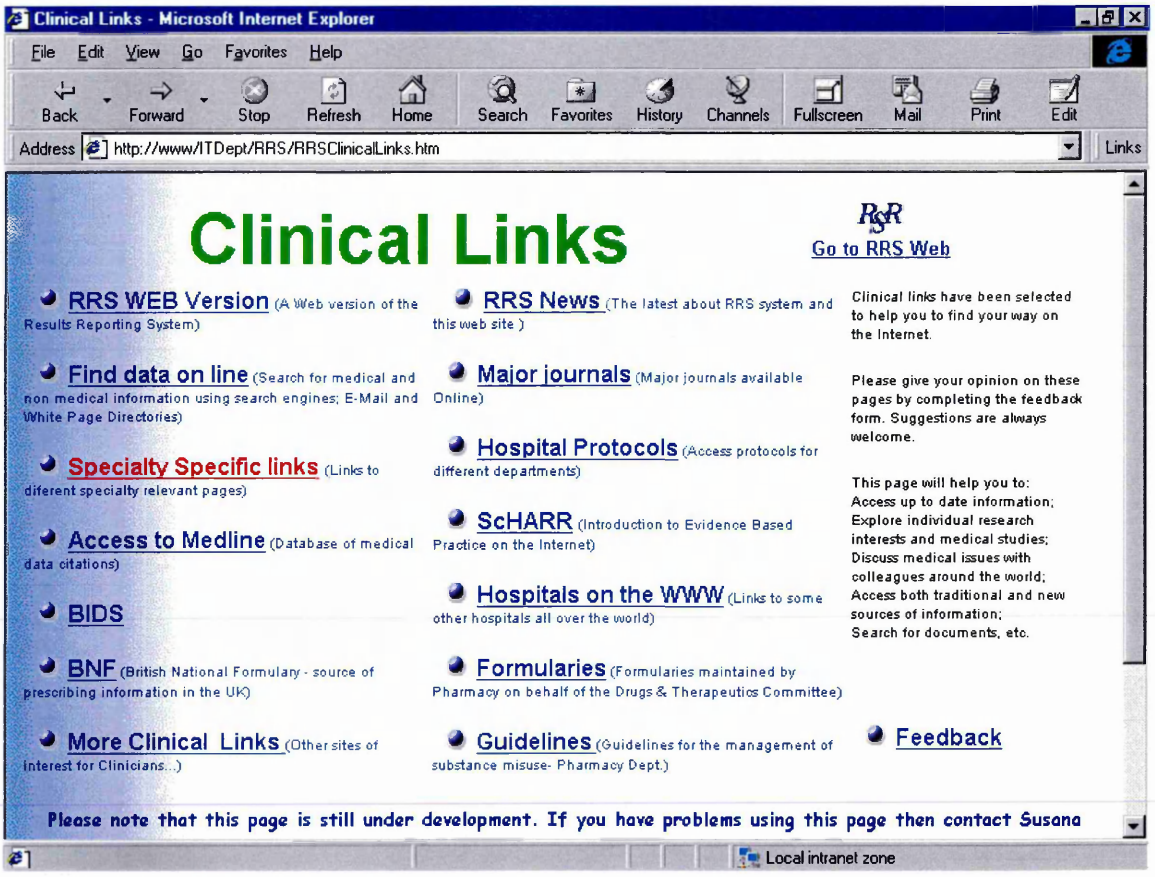

Figure 3. The links to reference information organised in terms of clinical specialty.

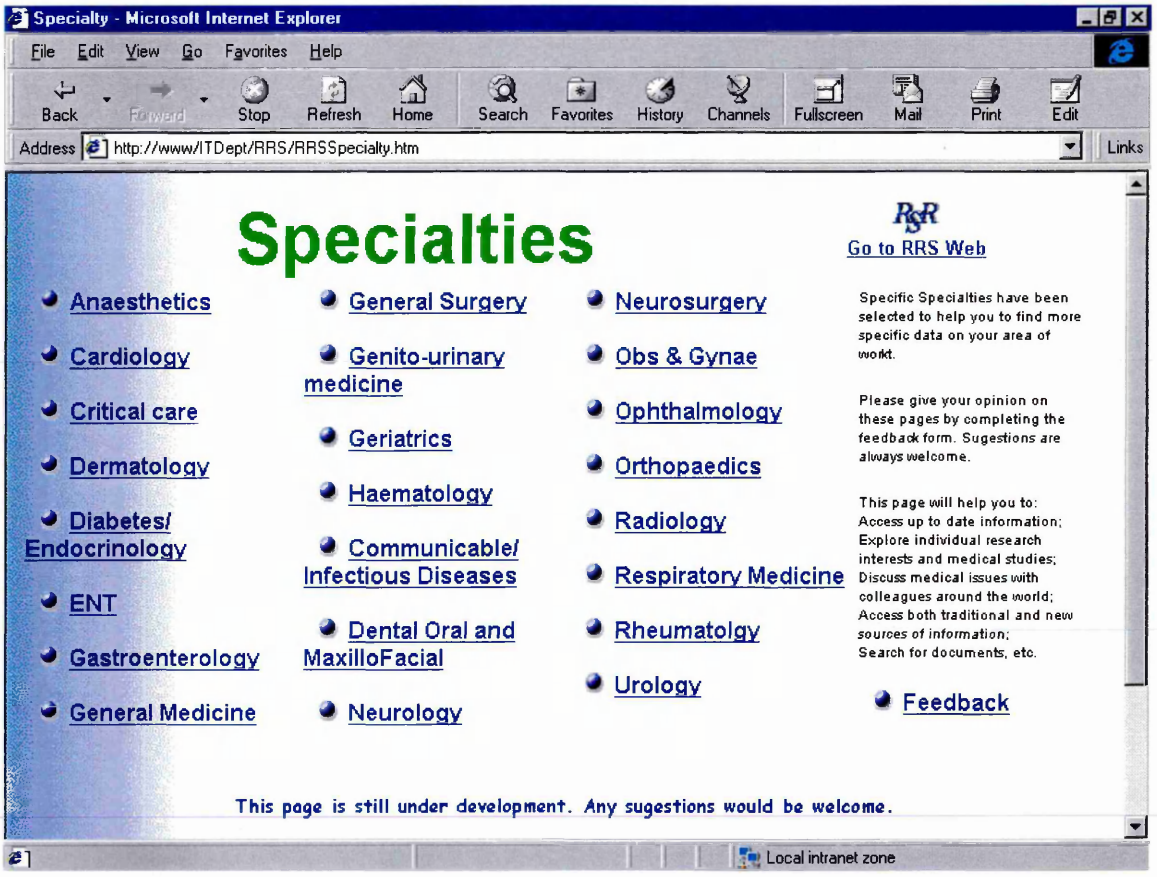

Figure 4. The specialty reference sources available on the prototype system for Geriatrics. This screen is reached by selection the appropriate specialty from the screen shown in figure 3.

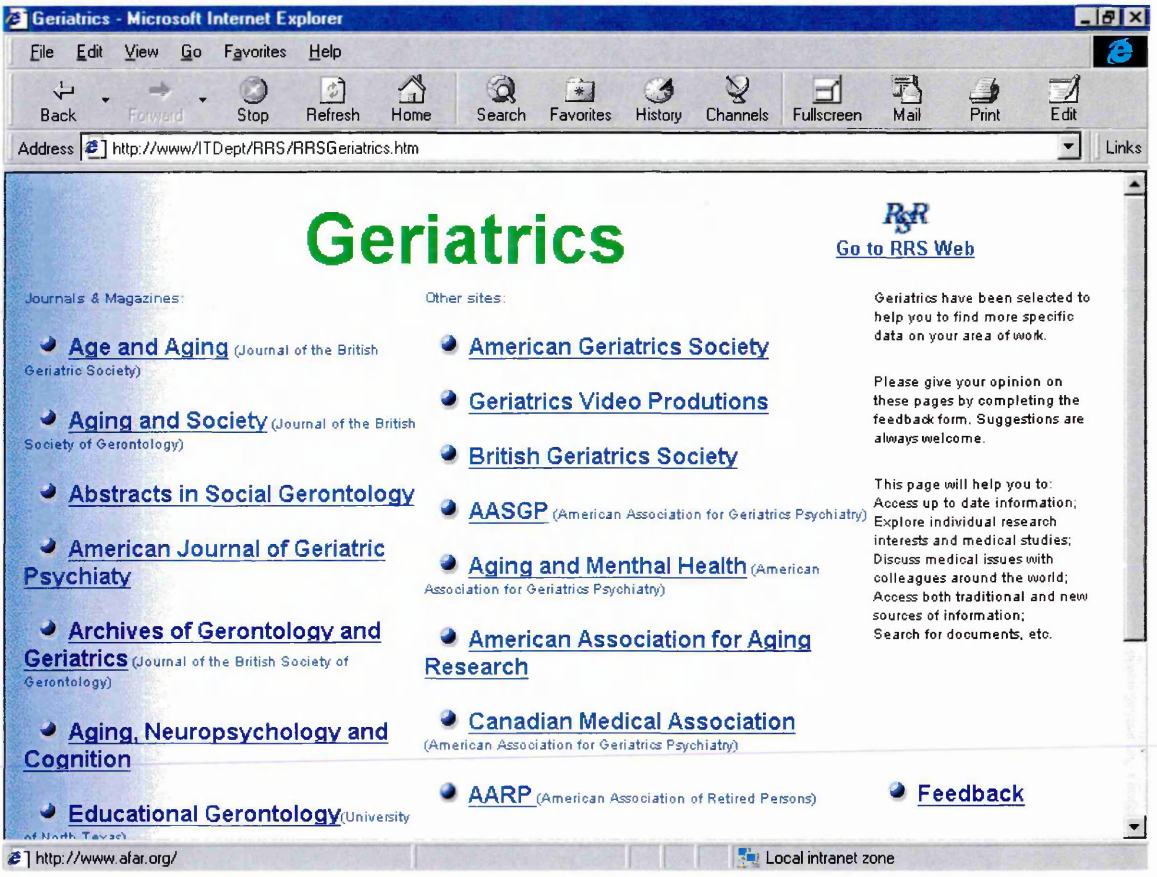

Table I – Value of information sources in the routine treatment of patients. Median of 5 point visual analogue scale

Patient Medical Record File	5
Clinical Information from RRS	5
Clinical advice from senior medical staff	5
Medical text books	4
Journals	4
Drugs Reference	5
Protocols for care	5
Clinical studies	4
Internal audit reviews	4

Table II – Information sources identified by users ranked by frequency of citation

BNF (British National Formulary)	25	MedLine (Database of medical article citations)	23
Protocols of care	15	Oxford Handbook of Medicine	9
Online Major Journals (e.g. BMJ)	3	BIDS (bibliographic service for the academic community)	2
Lancet (medical journal)	2	Medical text books	2
Oxford Handbook for Acute Medicine	2	Specialist sites	2
Blood Journal	2	Cochrane DB of systematic reviews	1
Library of conditions in picture	1	Guidelines for SHO/HO	1
Email	1	BMA (British Medical Association)	1
British Journal of Haematology	1	Guillians Haem. companion book	1
Haematology sites	1	Harrisons Principles Of Internal Medicine - *Stone, Richard M.*	1
American College of Physicians journal club	1	Pages with names of people on call for different specialities	1
Patient chronological list of admissions and clinical visits	1	Copy of the most recent discharge / summary clinic letters on line	1
Embase (biomedical and pharmacological database)	1	Society of Gastroentereology	1
Newsgroups	1	NEJn	1
RRS (Results Reporting System)	1	ListServers	1

Table III. Information source usage identified by 16 senior doctors as part of the evaluation of the first prototype workstation.

Sources of data used (includes multiple choices):	
Library	5
Inter/Intranet sources	13
Personal reference books	5
Time to find the required data:	
1 hour or less	11
1-3 hours	5
Purposes of looking for reference data (includes multiple choices):	
Confirm diagnosis	1
Identify treatment options	6
Personal Interest or research	12
Context in which the search for reference data was undertaken (includes multiple choices):	
Clinical concern	10
Clinical investigation	5
Research	3
Ward round	1
Post graduate lecture	1
Basis of this search (includes multiple choices):	
Diseases	10
Treatment	6
Specialty	5
Keywords	4
Drugs	2
Complications (drugs,etc)	2
Use of reference information from the prototype system (includes multiple choices):	
Medical search engines	13
General medical sites	12
Specialty specific Links	13
Medline	16
Medical journals	14
Electronic BNF	7
Other medical sites	2

Table IV. Results of the evaluation of the first prototype clinical workstation by 16 senior doctors.

Evaluation of information on ward based system ('yes' replies):	
The information provided was useful	11
The quantity of data provided was:	
Too little	2
Enough	14
Too much	0
The quality of data provided was:	
Adequate	13
Not adequate	2
Evaluation of navigation strategy ('yes' replies):	
Information on internet was easy to search and find?	13
Information accessed through the system was easy to search and find?	9
Was it easy to find specific information once an inter/intranet site was selected?	14
Is the information once found in a format that is easy to use?	15
Did the information retrieved fulfil expectations?	13
Was the information found appropriate to the problem identified?	13
Should the clinical links be expanded?	15
Do you prefer searching for data on computers rather than in books/ libraries?	15
Compare gathering data on the prototype system with the traditional methods ('yes' replies):	
The prototype system is better	14
The prototype system is more effective	14
The prototype system is quicker	14