Information technology in primary health care

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Abstract

Appropriate application of information technology in primary health care will extend traditional diagnosis and patient management beyond the doctor’s clinic into the everyday living environment. We describe a model of information management in primary health care, and place special emphasis on the emerging areas of clinical decision support, computerised clinical measurements, patient education and network connectivity. Briefly discussed is the design of innovative home monitoring techniques and a telemedicine based communications infrastructure that should improve access to high quality primary health care for all citizens, irrespective of their distance from major urban centres. A preliminary design for a telemedicine-assisted primary health care network is presented, based on this model of information management. The premise is that improvements in health care services and reductions in health care costs can be effected by establishing a continuum of patient care from the patient’s home, to the doctor’s surgery, to speciality services in hospitals and to other service providers in the health care sector. While, the proposal focuses on new opportunities arising from the imminent introduction of broad band interactive fibre optic networks throughout Australia, the technology and projected data transfers could easily be handled in the short-term using modem access to the standard telephone network. A simple connectivity scheme for system integration is also presented. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

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1. Introduction

It is now well recognised that achieving international best practice in the primary health care sector will require the development of methods based on a fundamental integration of communications and information technologies with clinical practice. This will have far reaching effects both on the pattern of medical practice and domiciliary care, and on patient outcomes.
The primary health care sector in Australia represents the base of the health care pyramid, and is formed by over 20 000 general practitioners, nurses, local area health services, community domiciliary nurses and community hospitals. This sector has a predominant role in the delivery of preventive health care and in the triaging of patients needing more expensive specialist or hospital services. Developments in health care worldwide are increasingly recognising the importance of this sector. Major advances in health care delivery over recent years have targeted; efficiency in the production of health care services and the management of health care resources; effectiveness in the selection of appropriate care services for delivery to the patient; and improvements in the quality of the services provided.

In Australia, the primary health sector is an economically important sector that controls entry into a health care system that now represents almost 8% of the gross domestic product (GDP). Integration of this sector with other specialist and local area hospital services using appropriate diagnostic and information based technologies will result in major cost efficiencies and improved public health outcomes. The impact of national strategies both in the UK [1] and Australia [2–4] for Information Management and Technology (IM&T) on general practice are likely to be profound, but many aspects of the implementation of these policies remain unclear. The objectives are to provide information-based resources to improve patient care, promote health prevention initiatives, improve practice management and provide continuity of information transfer between primary, community and hospital services. It is not at all clear however, how the medical practitioner and nursing staff will use information management and technology to improve the quality of care delivered to patients. Nor is it clear how this technology will help the doctor diagnose, treat and manage more effectively the chronic degenerative diseases that are characteristic of an industrially developed and ageing community.

In the primary health care setting, information and communications technology has in the past been presented as a tool for management rather than as a tool for supporting, improving and making more efficient the professional practice of medicine and the delivery of health care to the patient and the community.

As a consequence, many medical practitioners continue to demonstrate the same scepticism and lack of enthusiasm that has severely inhibited the introduction of information and communications technology in general practice over the last 10 years. Although the level of computerisation in general practice in Australia is now approximately 50–60%, GPs generally use their computers for accounting, billing and simple office management. Very few use their systems for clinical purposes or patient medical records [5]. More sophisticated applications such as clinical decision support, management of longitudinal data and the interfacing of clinical measurement systems into the patient medical record, are virtually unknown.

We present a model of information management in general practice, based on the perceived needs of the practitioner. It is envisaged that elements of this model will form the basis for a telemedicine-assisted primary health care trial. This trial will have as a broad objective, the provision of continuity of patient care from the patient’s home, to the doctor’s surgery, to speciality services in hospitals and to other service providers in the health care sector. The aim of the trial will be to assess the technology, as well as assess doctor and patient satisfaction. Longer-term
aims will be the assessment of changes in patient health outcomes and savings in health care expenditure.

The areas of clinical decision support, computerised clinical measurement and patient education are given particular attention as they represent novel and emerging activities in the computerisation of general practice. Methods of data exchange between these and other areas, and suppliers of patient management systems (PMS) are discussed. One simple connectivity method using file exchange is presented.

2. Information management in primary health care

The provision of information and communications technology to the primary health care sector has in the past been seen primarily from a management perspective, and even today this remains substantially the case [6]. Obviously information technology has an important role to play. From a UK perspective, the NHS IM&T [1] strategy for example, is intended to impact on general practice in a number of ways.

- Sharing more comprehensive GP data, will facilitate targeting of health care and assist preventive disease measures.
- Better care will result from access to a wider range of information, assisting GPs to make more detailed assessments of patients’ problems and better clinical decisions.
- Improved information systems will enable better monitoring and management of the practice.

It is not clear from any of these objectives how the medical practitioner will benefit professionally or what improvements are likely in the management of his/her patients’ health care problems. The benefits for the GP remain obscure and his/her willingness to computerise will be more related to the demands of the NHS or other legislative bodies, than to any real recognition of the value of information and communication technology in the exercise of professional practice.

In Australia, practice management systems presently in use have limited integrated communications capability, and communications dependent applications rare. Patient data cannot be either sent or received conveniently. Some doctors have modem connections to travel advisory services and databases on drug reactions but there is no public sector provision of databases on epidemiological, educational and public health issues. Some applications are beginning to appear for dial-in access to pathology results. The telephone and fax machine remain the most commonly used forms of communication in the GP office.

From an analysis of workload patterns and activities of the general practitioner, a representative model of information management in general practice can be formulated (Fig. 1). The central component, which includes patient records and practice administration, is common to all other activities because of the essential requirement for patient identifica-

![Fig. 1. A proposed model of information management in primary health care.](image)
tion, patient record keeping and patient billing. This activity has thus far received the majority of attention both in the IM&T strategy and from developers of practice management software. Lack of standardisation for medical coding and classification and the difficult and time consuming nature of keyboard data entry, however, continues to inhibit widespread use of the computer during consultations.

This standardisation issue has a wider impact, especially in Australia due to its geographic distribution and population density, resulting in a fragmented and relatively small market. Each PMS uses its own database structure and coding schema, thus the problem of integration with other modules, and networking with distributed resources including access to on-line services, is either difficult to implement or impossible due to differences in system configuration and competition to maintain market share [6]. Moreover, a significant number of legacy computer systems may not even have networking capabilities.

Whilst some 30% of doctors in the UK have a computer on their desk during the consultation, few use it for data entry and retrieval of coded clinical information. The situation is similar in Australia [6]. Computers are still most commonly used by reception staff and practice nurses. There is no doubt however, with an increased awareness of the Internet and the role which telecommunications could play in information retrieval, that this trend is reversing. Indeed, it is the additional information management components as illustrated in Fig. 1 that are the driving forces behind the changes.

Three key elements of information management and technology in general practice are becoming of growing importance as they directly affect the GP’s work practice. These are computerised clinical measurements, clinical decision support and integrated patient education. These areas are described in detail in subsequent sections, with emphasis on research and development activities that are currently underway in our laboratories in these specific areas.

Other areas of national interest include systems for data gathering and collection. While such modules are of limited immediate benefit to the GP, longer-term benefits may be gained. For example, through the collection of de-identified patient/doctor data, epidemiological studies could highlight disease outbreaks and geographical clustering of disease conditions. With advanced data mining techniques, treatment and dispensing information could for the first time be correlated with patient outcomes.

Other areas that are increasingly receiving the attention of PMS suppliers as they compete in the market place, include, clinical records, Internet access and prescription writing software linked to drug databases.

It is significant to note that all of the previous components are becoming reliant on an on-line network connection to increase their functionality and ease of use. Typical uses include on-line access to databases, journal information, web resources, software updates and patches, results of clinical tests and local practice Intranets.

2.1. Clinical measurements

Accurate, quantitative measurement is an essential component of the decision making process in nearly every profession. The use of sophisticated clinical measurement equipment in specialist and hospital medical practice has certainly contributed to the increasing status and influence of that sector of the health care pyramid. Contrary to common belief, however, the cost of medical equipment and devices, irrespective of their sophistication and complexity, represents less than 2% of
total health care expenditure. Analysis of present and projected clinical needs of the GP suggest that 90% of his or her requirements would be met from combinations selected from the following instrumentation modules:
- Electrocardiography (ECG);
- Spirometry (lung function analysis);
- Basic haematology, blood and urine analysis;
- Non-invasive measurements of blood pressure, heart rate, weight, temperature and circulatory function;
- Audiometry and auditory evoked responses;
- Ambulatory monitoring of at home patients-ECG and spirometry.

Clinical instruments are uniquely characterised by their transducer function. Other features such as data acquisition, computational requirements, data input/output facilities and hard copy options, are relatively common to all instruments. This suggests that a modular approach to the design of clinical instruments based on common PC technology, coupled with a common user interface, and database facilities integrated with patient and clinical records, would provide an attractive and cost effective solution for the clinical measurement requirement of the general practitioner.

One solution to integrated clinical measurements in the primary health care setting has been designed and developed in our laboratories [7]. The approach is to design the clinical measurement system in such a way that it can easily be interfaced to the PC (by a plug-in card using an ISA bus or PCMCIA interface, or by serial connection). The data should then be readily accessible to a database for storage, retrieval and subsequent analysis. Fig. 2 shows a sample screen from our PC-based ECG system called WIN-ECG. This system includes a PC-based interface card for patient safe recording of 12-lead ECGs.

All measurements are recorded and displayed in real time on the computer monitor using advanced graphics and a sophisticated user interface for ease of operation. These clinical measurements are integrated with an electronic medical record for storage, retrieval, measurement and interpretation.

The ECG module provides the ability to record electrocardiographic signals with exceptional fidelity and quality without unnecessary filtering or processing. The design of the electronics incorporates a number of novel new features. The ECG card has been designed and tested to the IEC601.1 standards for patient safety and operation. To achieve the appropriate levels of isolation in a PC, careful design of the isolation barrier between patient and computer was required. For this purpose linear opto-isolators were used as a good compromise between signal fidelity and cost of manufacture. Low pass filtering to reduce high frequency noise outside the range of interest and to eliminate anti-aliasing errors is also carried out in hardware. A patented filter design is used, which offers close to ideal characteristics of a flat pass-band response, a rapid attenuation in the stop band and linear phase response. As a result the ECG signal is filtered without any significant phase or magnitude distortion.

Automatic control of gain and offset have been incorporated so that ECG signals are always recorded and digitised with maximum sensitivity. This feature is of particular importance in the detection of late-potentials, and together with the high frequency bandwidth option, provides many opportunities for use of this instrument in clinical research should the GP choose to be involved.

The spirometry (lung function) module (PC-SPIRO) provides facilities for the recording and analysis of forced expiratory and inspiratory flow and volume signals to assess
lung function. The flow transducer is based on the hot wire anemometry principle and is linear over flow ranges of 0–600 l/min. The spirometer has a frequency bandwidth of 200 Hz and is temperature compensated at 37°C. The transducer is simple in design and robust in construction to withstand continuous use and permit easy cleaning and maintenance.

Some of the advantages of the PC-based approach to clinical measurements are:

- the systems are relatively inexpensive as analysis, display and printing are performed on the GPs computer;
- upgrades and enhancements can easily be distributed by software revisions;
- ECG data can easily incorporated into an electronic medical record;
- longitudinal data comparisons are facilitated;
- paper recordings of ECG waveforms are unnecessary;
- as the data is already digitised into a computer readable form it is a simple matter to incorporate the information into a report for distribution automatically over a network or manually by FAX or modem;
- the professional role of the GP is enhanced by the use of appropriate clinical measurement technology.

Fig. 2. Win-ECG recording and review screen showing automated ECG measurement markers for P wave onset, QRS onset, QRS offset and T wave offset.
2.2. **Clinical decision support**

Some 85% of the variance in patient costs when all other factors are accounted for can be explained by differences in clinical management. Similarly between 50 and 60% of referrals to specialist services are unnecessary. The economic cost of incorrect or unnecessary clinical decisions both in terms of service costs and lost hours of work are very large.

Most clinical decisions are taken during the patient visit, and depend on the available clinical history of the patient. The more complete the clinical record, the more confident the doctor will be in the making of his or her decision. Clinical histories should thus include free text information, as well as clinical data entered using some structured hierarchy of medical terms. The Read codes, the international classification of primary care (ICPC) codes or from the Australian perspective, the international classification of diseases 10th revision with Australian modifications (ICD-10-Am) codes [8], are examples of coding schemes that could be adopted. Objective clinical measurement data such as ECG or spirometry should also be available for review, either in summarised form or in the original graphical form. On-screen, simple to use facilities must be available to compare historical data with newly acquired data, and to graph trends in key variables for longitudinal comparison.

This clinical decision making process can also be enhanced with inductive reasoning and expert systems which use epidemiological and statistical data to calculate risk factors and offer alternative management strategies. Similarly, agreed protocols based on age, sex and specific risk factors can be used to optimise the clinical decision process and to protect the medical practitioner against malpractice claims. The fear of litigation is in many parts of the world a major incentive for the over-prescribing of costly tests and procedures.

Many of the morbidity patterns associated with old age are chronic and degenerative and very difficult to treat. The time course of changes in clinical symptoms and of objective diagnostic parameters is particularly important in the clinical management of the aged and is becoming increasingly important in difficult to treat conditions such as asthma. Use of the longitudinal clinical record for clinical management of at-risk patients is almost unknown, yet holds great promise as an important tool for optimising patient outcomes and minimising costs in general practice.

In the specific case of ECG diagnosis, the expert systems associated with automated interpretation are quite well advanced. As an example, the diagnostic performance of traditional rule-based expert systems for detection of anatomical lesions and pathophysiological states is accurate in 76.3% of cases, where a panel of cardiologists is accurate in 76.9% of cases [9]. In our laboratory we have employed artificial neural networks to increase the diagnostic accuracy over traditional rule-based approaches [10]. An example of our clinical decision support system for automated ECG interpretation is shown in Fig. 3. Using this system we can classify between normal and abnormal conditions (including ventricular hypertrophies and myocardial infarctions) with an accuracy of 88%.

2.3. **Patient education**

Computer-based patient education is becoming of increasing importance to the GP. From a duty-of-care consideration, it is useful to have recorded a summary of the educational materials distributed to the patient. Moreover, structured patient education has
been shown to improve patient satisfaction without adding to the consultation time [12].

As one example of integrated and comprehensive patient education, we describe our EDU-CATE module [12], which is an acronym for Computer Access To Education. It is a system which aims to provide a user-friendly computer package of patient education 'leaflets' that can be effectively used in primary health care. Appropriate formats, characteristics and topics have been identified for the leaflets by researchers at the General Practice Unit of Fairfield Hospital (Sydney) and from the School of Community Medicine at the University of New South Wales, Sydney, Australia. In a similar manner to the clinical measurement modules, a database front-end is used to track usage of leaflets by individual patients, overall distribution of leaflets by doctors, and maintenance of leaflet version information. The database also allows easy installation of additional leaflet series, as they become available.

To date, 11 series on asthma, diabetes, cardiovascular health, osteoarthritis, childhood immunisation, anxiety, depression, childhood illnesses, gastrointestinal disease, hospitalisation and home care and general

![Fig. 3. Win-ECG clinical decision support module providing ECG measurement information along with the age-adjusted normal range, as well as an overall interpretation of the ECG in terms of seven possible disease categories.]
medical issues have been developed. Each series comprise approximately 12 leaflets that cover issues from cause of the disease, to symptoms, treatments (including management, side effects and dangers of not being treated) and resources available for self-help and support. This depth of treatment of a particular disease or condition, is a distinguishing factor of EDU-CATE over other patient education materials available within Australia in either paper-based or electronic form. The leaflets comprise text, diagrams and space for GP details and specific patient instructions. The leaflet can be provided in a paper form for the patient to take home and read or can be provided via the computer screen on the doctor’s desk, as a structured form of patient education within the consultation. An example computer screen from the cardiovascular health series is shown in Fig. 4. The text for the on-screen information is directed at a simplistic level so that people from various educational backgrounds can readily understand the information content. Issues relevant to the computerisation of the educational materials included:

(1) Making the software accessible to a wide range of computer users by choosing the Microsoft Windows operating environment running on IBM PCs or compatibles.
(2) Using authoring tools that allowed incorporation of scanned images and line drawings to be displayed, along with brief descriptive text in a format suitable for interactive review of the screen information by GP and patient.

(3) Programming a database front end (currently Visual Basic using a Microsoft FoxPro database structure), in order to track usage of leaflets by individual patients, overall distribution of leaflets by GPs, and maintenance of leaflet version information. Leaflet selection from within the database is very similar to that of procedure selection within the Clinical Measurement module.

(4) Background printing of a leaflet while the GP is discussing the leaflet content on-screen, with the patient.

The EDU-CATE project is on going, with other leaflet series under construction. These include series on maternal health, sexually transmitted disease, cancer, palliative care, epilepsy, stroke, menopause, schizophrenia and incontinence. In addition, a number of the leaflet series are being converted to other languages. Other tasks under investigation include the addition of full motion video clips in the leaflets, as well as access/distribution of the EDU-CATE software over either standard or dedicated telephone lines.

3. Communications and networks

For telemedicine to impact on general practice, a communications network must be in place. Interestingly, in the UK, some 40% of all activities of the NHS are associated with the handling and communications of data [1]. The NHS IM&T strategy has indeed targeted networking and the facilitation of communications between GPs, community carers and hospitals as one of its major objectives. Activity however seems to be concentrated on the establishment of standards for electronic data interchange and to ensure confidentiality and security. Again the entire effort is focused on the transfer of administrative data and service claims between the GP and the NHS. The use of communications technology to support the clinical management of patients in general practice scarcely rates a mention.

The opportunities for cost effective uses of communications technology in general practice are large. Over 200 million consultations per annum are carried out by GPs working from over 10 000 sites in the UK. General Practice Medical Workstations providing clinical measurement and communications capabilities as an integrated easy to use facility, would rapidly generate line activity through data interchange and consultation with specialist medical services, local community health services and hospitals. The level of integration and ease of use of the facilities provided will determine the level and speed of acceptance of communications as an integral part of medical practice.

Any clinical, text or graphical record visible on the doctor’s screen must be able to be easily attached to an internally generated covering letter and sent via fax or modem anywhere. There are many situations where this facility for transferring relevant patient data to a hospital or to another doctor is important. As over 50% of referrals to specialist services are unnecessary, an obvious application would be the transfer of patient clinical data, rather than the patient, for specialist opinion. This would result in large cost savings in service fees and a reduction in hours of time lost by both patient and practitioner. Communications facilities would also be used to gain access to travel advisory services, drug adverse reaction data, immunisation data and other databases containing epidemiological and public health informa-
tion. Medical education programs, similar to those provided by the Open University could become an essential element of ongoing postgraduate medical training.

At this point in time, most immediately feasible applications can be met via the use of the PSTN network and a simple fax/modem card. The telephone transfer of a high resolution 12-lead ECG in graphical form requires for example, the transmission of 80 KB of digital data if data reduction or compression is not used. Certainly, as the need for the transfer of images and for video teleconferencing develops, the fibre-optic broadband network will be necessary to supply the increased bandwidth and performance requirements.

3.1. Open systems and connectivity

The key is integration and connectivity. No single PMS supplier can provide the diverse range communications, database and application software needs for all GPs. Similarly, it is to the advantage of both the GP and the medical software industry, for the GP to have choices as to what software components or modules are best suited for a particular practice. The only approach is therefore to promote a consistency of standards that form the foundation of a diverse range of software solutions. One good example of successful information technology integration is reported by Shepherd [13] using solutions based on a Good European Health Record (GEHR) compliant clinical database and communications enabling software implemented on ‘gateway’ PCs to facilitate data exchange.

In Australia, due to market issues and legacy systems, there is very little network integration and connectivity between systems and sites. This is likely to change in the near future with a number of Government and other initiatives examining common frameworks and inter-operabilities between software products [11].

The approach that we have adopted for our PC-based clinical measurement systems and for our patient education module is to design the systems in such a way that they can function stand-alone. In stand-alone mode, a database front-end is used to record patient data as well as clinical measurement procedures or patient leaflet usage. This approach is of limited value from a telemedicine perspective. For this reason, a design philosophy was to separate the database functionality from the speciality functions of the particular module. When integration is required, the database front-end can then be replaced by a database system installed by a third party PMS supplier.

As our systems are designed around Windows 32-bit systems, communications between the database and the specialty module could have been via a number of different standards for accessing data. Health messages using HL7 and coding using ICD-10-Am for disease classifications could have been employed to exchange data with other third party PMS suppliers.

In our clinical measurement, clinical decision support and patient education modules, it was decided not to adopt any of these inter-application messaging and coding standards for two reasons. A large number of legacy systems currently in use in Australian GP computing cannot use these approaches. Secondly, the actual standards and approaches likely to be employed in Australia are currently under investigation by a number of parties, including Government, GP and industry bodies.

Instead, we adopted the simple communications scheme shown in Fig. 5. In this scheme, simple file creation is used to pass information. A patient/task descriptor file is
passed from the database to the specialty module. This file contains patient information that may be necessary for the target module (e.g. patient name, age and sex for ECG measurements and reporting). This information is coded using simple text tags. A second file is used for two-way communications. This file contains the proprietary binary large object (BLOB) created by the target module. As an example, when acquiring a new ECG, the clinical measurement module will create the BLOB. It is then the responsibility of the database program to save this BLOB as a record in an appropriate database structure. When reviewing or printing an existing ECG procedure, the process is reversed, with the database supplying the BLOB information and the specialty module processing the data appropriately.

By the use of simple interface standards and protocols, both clinical measurement, patient education and clinical decision support modules can be integrated very easily with existing patient management systems. Typically, a third party PMS supplier could perform the integration process in less than a day. As legacy PMS systems that do not adopt standards become less common.

As the Australian standards for GP computing are clarified over the coming years, it will be a relatively simple matter to modify the current schema to employ the adopted messaging and coding standards.

4. Telemedicine trial

Using individual modules and the simple connectivity scheme described previously, a telemedicine trial is proposed. Plans are currently underway to produce lower cost and simpler versions of our clinical measurement modules for home use (single-lead ECG and spirometry). It is envisaged that a central service provider will automatically collect the data from the patient’s home initially via the standard telephone (PSTN) network. A database server will act as a central repository for this information, which will be made available on request from the doctor’s PC.

The doctor will have access to a range of modules integrated into his or her patient management system. That is, the GP will be presented with a ‘managed desktop’. This desktop will have the option of being configured and upgraded from the central service provider, using a web browser style interface. Similar systems will be installed in a number of teaching hospitals for access to specialty cardiology services.

5. Conclusions

This paper has attempted to address some of the issues involved in modelling information management in the general practice setting, and hence a telemedicine trial with a focus on continuity of care. For such a trial to be a success many other issues need to be resolved. They include:

(1) confidentiality and secure exchange of clinical data to the satisfaction of the privacy commission;

(2) tools for the assessment of the quality and provision of health care, patient satisfac-

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Fig. 5. Simple connectivity scheme for transfer of clinical data between legacy and other software systems.
tion and health status, and cost effectiveness of the health care management concepts;
(3) implementation of messaging standards, communications protocols and network support for the exchange of clinical data using the standard telephone network, the digital mobile network, and the interactive broad-band network;
(4) standards and protocols for the automated collection of clinical epidemiological data for research purposes;
(5) provision of value added services, including patient education, document conferencing and expert system shells for improved patient management via automated risk factor analysis;
(6) automatic integration of clinical measurement data into patient records.

What is clear from previous discussion papers and market analysis is that there is enormous potential for economic benefit and improved health outcomes through the appropriate and timely implementation of telemedicine. In the USA, Arthur D. Little Inc. (1992) estimated that cost reductions in the order of US $15 billion per year (1990 prices) could be achievable by the use of telemedicine to support home health services, as compared to institutional care [14]. In an Australian study, Rockcliffe et al. (1992) as cited by Crowe [15] drew similar conclusions in regard to cardiac monitoring for follow-up of patients who have had either pacemaker procedures (4300 patients) or cardiac arrhythmia treatment (21 990 patients). Their estimates suggested that average hospital stays might be reduced from 1.5 to 5 days with a potential annual saving of $2.6M.

In this paper a framework of information management in primary health care has been suggested. A number of key elements of clinical service provision have been highlighted, including integrated clinical measurements and computerised patient education. The importance of an appropriate network, communications and computing framework is evident. Less evident, though equally important, is the thesis that telemedicine, personal computing and integrated management software, will be essential factors in ensuring that a holistic approach to information management and technology is provided to the general practitioner to facilitate best practice in the primary health care sector.

References


