

Chapter 3. Health Informatics and Computing

Integrating the Healthcare Enterprise (IHE) and the Electronic Patient Record (EPR)

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Introduction IHE is concerned with interoperability of hospital information systems and service department systems. This includes handling diagnostic service requests and the delivery of results. The results of diagnostic procedures that are stored in electronic form include text, numerical results and results such as images and graphs that are referenced by diagnostic service reports. In this paper we consider only results of diagnostic service procedures that are made available outside the service department within the Electronic Patient Record (diagnostic procedure products).

Diagnostic procedure products stored in electronic form

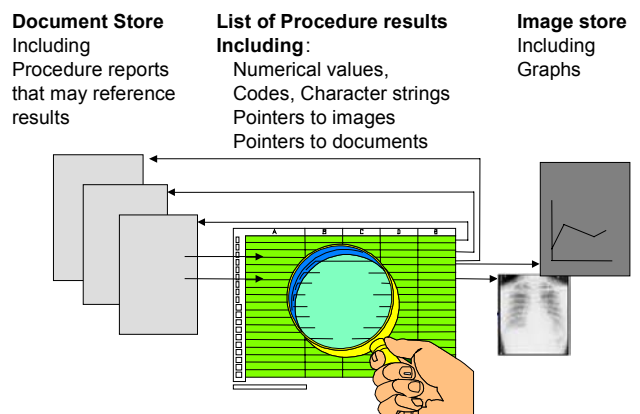
A simple structure to hold the results of diagnostic procedures in electronic form comprises a comprises:

1. A store for documents in electronic form such as reports, some of which include references to results such as numerical values or images
2. A list of results including numerical values and image references such as might be stored in spreadsheet form
3. A store for digital image data in electronic form including pictures and graphics objects.

The list of results will usually be stored in a database that reference procedure codes, requesting clinician codes, procedure result types etc. However this data may be represented by a single spreadsheet and archive stores (see figure). The IHE provisions regarding the format of procedure products in electronic form provide an excellent basis for the

specification of the columns of this spreadsheet. Complex relationships may be expressed within the documents (e.g. DICOM SR [1]). Some simple relationships such as the identity of a result such as an image that was used to obtain a measurement such as the diameter of a body structure (.e.g. a blood vessel) may be included in the spreadsheet format.

Results of diagnostic service procedures in electronic form



Conclusion This model provides a basis for discussion regarding this important part of the Electronic Patient Record

References

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Integrating the Healthcare Enterprise (IHE) in the UK

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Introduction The Integrating the Healthcare Enterprise (IHE) is an initiative that will impact the work of all hospitals and clinics. It was launched by the Radiological Society of North America (RSNA) and the Healthcare Information and Management System Society (HIMMS) in the USA and enables interoperability of IT systems [1]. The domain of IHE extends from registration of the patient on arrival at the hospital through requesting of diagnostic procedures and provision of access to procedure products in electronic form.

UK Needs An IHE Europe committee has been set up to enable appropriate implementation of IHE provisions in Europe [2]. There is a requirement for a UK initiative to ensure that specific UK legislation and methods of practicing medicine are supported by industry and the professions. A multi-professional UK committee has been set up which includes members from the IPEM, the British Institute of Radiology, the Royal College of Radiology, the College of Radiographers and representatives from government departments including the Medical Devices Agency and the NHS Information Authority. This UK committee organises demonstrations of IHE interoperability and feeds details of UK specific needs to the IHE Europe committee, which acknowledges the need for national specific provisions but seeks to minimise them. Although the IHE initiative is currently focused on diagnostic imaging and PACS, the techniques developed will spread throughout the institution or enterprise.

Benefits Interoperability problems between IT equipment within hospital departments impede effective exchange of medical information within the healthcare enterprise. These problems arise from varying build-standards and design-age differences of the IT equipment. IHE promotes the co-ordinated use of established IT communication standards in an incremental fashion. This approach will eventually lead to an integrated healthcare enterprise. Improved efficiency and better patient management are obtained as a result of improved interoperability of systems.

References

[1] www.rsna.org/ihe

[2] www.ihe-europe.org

PACSnet and Integrating the Healthcare Enterprise

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Introduction PACSnet was established by the Department of Health Medical Devices Agency to be the centre of expertise in the UK in PACS evaluation. The unit provides information and assistance in the implementation of PACS solutions. As part of PACSnet's remit the unit has also been involved in the preparation of documents produced by the BIR relating to IHE. In particular the Diagnostic Imaging Scenario and IHE Implementation Guide. The object of the IHE initiative is to enable interoperability of systems within a healthcare enterprise.

Interoperability Interoperability is defined in the UK IHE documents as "a state which exists between two application entities with regard to a specific task when

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one application entity can receive data from the other and perform the task in a satisfactory manner". In order to achieve interoperability it is necessary to a) define the tasks that need to be performed b) identify the data required to support the task c) define the processes to be applied to the data and d) implement the systems (hardware and software).

IHE Integration Profiles IHE specifies a number of profiles of existing standards (HL7 and DICOM). A profile is a sub set of the provisions of a standard. In IHE, exchange of data between systems is described in terms of Actors and Transactions. The Scheduled Workflow and Simple Image Numeric Report profiles defines the Transactions required in order to perform a diagnostic imaging procedure from receipt of a requests thorough image data acquisition to reporting and the supply of procedure products to the referring clinician.

Evaluation of PACS and IHE The specifications of the IHE Integration Profiles provide a valuable framework for the evaluation of PACS systems. Alignment of system design with IHE profiles is something which should be considered when purchasing PACS.

IHE as an aid to system implementation in the real world

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Introduction PACS is being introduced to ensure reliable distribution of images but a film packet bearing a miss-spelled name may fare better than its electronic equivalent.

The IHE initiative [1] identifies a set of standards for use in distinct areas of healthcare information management. It specifies how these standards should be used to ensure that distinct systems can be integrated effectively. IHE currently supports integration of imaging and central hospital systems, i.e. scenarios involving PACS. In the future IHE will address wider issues and has the potential to extend to other service departments.

The need for analysing and understanding workflow

A challenge for those specifying and implementing systems is to understand existing process flows, not just as they are supposed to work but also how they actually do work. This can be achieved by developing a general understanding of activity within and around the imaging service and having a formalism for describing and cataloguing this. Documents have been developed with the assistance of the BIR to provide an aid for formal description of practice in the UK.

IHE as a tool for analysis and specification For the imaging domain IHE identifies DICOM and HL7 as the key standards. In order to specify the functionality that is required to meet a specific objective, a sub-set of each standard is identified that is sufficient for this objective. These sub-sets are known as integration profiles.

This presentation will discuss the contribution that IHE, in conjunction with the BIR documents, can make to analysing and specifying systems in typical UK hospital environments. It will address the use of IHE in the presence of legacy systems and the extent to which manual or less than ideal procedures can be accommodated.

Reference

[1] www.rsna.org/ihe

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The development of a Trust wide imaging network at Guys and St Thomas' NHS Trust

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Introduction In 1997 a working party, comprising the departments of Medical Physics, Radiological Sciences and Information Technology, at GSTT was awarded a grant to develop a medical imaging network that would meet the urgent requirements of digital imaging modalities within the Trust.

Methods The working party drew up the technical requirements for a network infrastructure that would take into account bandwidth issues and security requirements as outlined by the NHSnet. In particular there was a need to develop a solution that would allow patient images to be incorporated to hospital information systems while also allowing access to researchers. After independent assessments by DERA, the working party recommended an ATM backbone with Ethernet edge device network. The key feature of this technology is;

Configuration of the network into secure and insecure sides through the use of Emulated Local Area Networks (ELAN's) with individual port security maintained by port locking via MAC address.

Results An imaging network has been developed at GSTT. Its main components are;

- A Kodak and Siemens PACS.
- Communication between over 100 imaging, reviewing and reporting stations with workflow management through the HIS and RIS.

- Communication between research machines with access to patient images via NHSnet approved Checkpoint Firewall 1.0.
- Tele-medicine and video-conferencing capabilities.

Conclusions The development of a large digital imaging network across two hospital sites with access to both the NHSnet and JANET has provided a framework for the development and migration of such networks to future topologies and technologies. GSTT is at present developing the infrastructure for Gigabit Ethernet across the trust to accommodate further projected increases in IT usage. Lessons learnt during the implementation of the ATM imaging network have provided a useful basis by which the new Gigabit infrastructure can be implemented taking into account bandwidth requirements, issues of patient confidentiality and access of images for research purposes.

Survival prediction of head and neck cancer using artificial neural networks

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Introduction Head and neck cancer is among the more curable of malignancies. It is the sixth commonest cancer in the UK. Approximately 60% of patients with this disease are cured and the success of treatment continues to improve [1]. Regrettably, head and neck cancer is associated with a high second cancer rate of between 10 and 25% over a 25-year period [2]. Flexible modelling in survival analysis is useful as both a diagnostic adjunct and a

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prognostic indicator. Since artificial neural networks can be regarded as flexible models suitable for non-linear multivariate problems, they have been applied to several classification and prediction tasks in the biomedical field to improve diagnostic or predict outcome.

Method Multi-layer feed-forward artificial neural networks were used to predict survival from the Liverpool Head and Neck Database on laryngeal cancer containing 1069 records. Networks inputs were:

- Histology
- T stage
- Performance status
- Level of nodes
- N Status
- Metastases
- Second tumour

Time to follow-up was coded as a further input. Networks were trained to predict the probability of relapse over a discrete time function.

Results The networks were able to predict 5-year survival with 90% sensitivity and 83% specificity. The survival function curve produced by the network closely resembled the observed data.

Conclusion ANNs can successfully model non-linear interactions of data in predicting survival. Further optimization of network parameters might improve prediction still.

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Fuzzy logic expert system for ventilation of newborn infants

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Introduction Mechanical ventilation of newborn infants is adjusted according to the level of blood gases and this process is governed by rules. Expert systems are therefore feasible in this situation. Fuzzy logic has been used for developing expert systems as they can provide acceptable solutions within a reasonable time period. Our aim is to develop a computerised decision support system for ventilation of the newborn infant using fuzzy logic.

Methods A multi-stage fuzzy logic expert system was developed using MATLAB 5.3 (Mathworks, Natick, MA). A set of 20 scenarios featuring different oxygen/carbon dioxide abnormalities under different ventilatory conditions was created. The fuzzy logic expert system was tested on these scenarios in the Simulink® environment. The answers derived were then graded by a panel of neonatologists and respiratory paediatrician, who had evaluated the scenarios beforehand.

Results The fuzzy logic expert system was judged to give acceptable solutions to 17 of the 20 scenarios. In the 3 where there was disagreement, it was agreed that the solution from the system would lead to partial correction of the blood gases. None of the solutions in the 3 cases was felt to be potentially unsafe. There

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was strong agreement with the solution provided by the expert system in 6 of the 17 cases; the remaining 11 cases were felt to give qualitatively the correct answer.

Conclusion A decision support system for ventilation of the newborn infant using fuzzy logic is feasible. This pilot study will be followed up by a larger scale assessment using the DELPHI technique.

The development of an intelligent patient monitoring system in the neonatal intensive care unit (NICU)

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Introduction With babies under artificial ventilation, any change in the ventilator setting is aimed to improve the patient oxygenation and ventilation status. The direction and time of improvement is expected to follow a predefined normal behaviour of each parameter. If a parameter did not follow the normal expected qualitative trend proposed by a template, a clinical intervention would be needed. We have shown previously that artificial intelligence is a powerful technique in rejecting measurement artefact [1]. This paper describes an open-loop feedback intelligent system for neonatal intensive care management. The system requires the user to make the final decision thus becoming a tool to aid and not replace the clinician.

Method The idea of trend templates was initially proposed and implemented in [2]. We have enhanced

this technique using fuzzy descriptions of the parameter value and its trend. The qualitative categories for the parameter value and trend are used after taking into account the period of parameter abnormality as inputs to a fuzzy advisory system for oxygenation and ventilation management. Seven neonates, age 27-31 weeks were monitored for 124.13 hours ($\mu = 17.7329$, $\sigma = 5.3843$ hours, Range = 10.40–23.85 hours).

The validation mechanism is executed by comparing:

- The recommendations triggered by the system with the user feed back (agree, disagree, wait)
- The user's actions with the system recommendations.

Results Seven users (3 doctors and 4 nurses) performed the validation process. The sensitivity of the system recommendations in respect to oxygenation is 83%, the specificity is 90% and the accuracy is 85%. The sensitivity of the system in respect to ventilation is 93%, the specificity is 80% and the accuracy is 91%.

Conclusion Preliminary results indicates that fuzzified trend templates can be used in a real time expert system for patient monitoring for detecting significant development in the patient respiratory status.

References

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A Multi-Site Multi-Service Client-Focused Database for Community Healthcare

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Introduction The Service to Aid Independent Living in Hull runs eight client services: Wheelchairs, Continence Management, Medical Equipment, Dietetics, Physical Disability Nursing, Environmental Control, Continence Advice and Social Service Loans (joint with local Social Services) to a similar client group. The current system, WinTAS, is built upon a computerised system for the Wheelchair service [1] merged with systems for Continence Advice and Medical Loans [2]. This ran within two Community Trusts. Their merger saw a requirement for the data to be merged and the system to run multi-site. The opportunity was taken to implement a move from a DOS-based system to a Windows-based one [3].

Methods The original system was written in Clipper and the new system in Visual C++ (SQL Server back-end), carrying forward the business logic into the new environment.

Implementing a new system gave an opportunity to introduce a subtle shift in business paradigm from “what operation do I wish to perform and who do I wish to perform it for?” to “who is the client and what do I wish to do for him/her?”, mirroring the move from an equipment-centred to a client-centred methodology within the service.

Results WinTAS produces all paperwork for the eight services, as well as recording all client activity from clinic visits to telephone conversations. There are presently 128 reports returning information from simple lists to complex aggregations.

The system has proved reliable and easy to use. It is real-time in that staff receiving telephone calls have

relevant data on-screen in less than a second and enter new information during the conversation.

Conclusion Databases are a vital yet unglamorous part of Information Technology. When reliable and well-tailored to the service they seek to serve they move beyond the role of “useful tool” to that of “vital part”. WinTAS is such a system.

References

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Integration of Presentation Style with Presentation Software

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Introduction The almost universal use of Powerpoint as presentation software has led to a homogenisation of presentation style. Whilst this in itself may not be a bad thing (it has certainly reduced the plethora of smudged, grainy OHP transparencies that blighted many a scientific report) it has led instead to “viewer fatigue” as the varying styles that used to keep listeners alert and attentive are homogenised and blurred into one long, similar, presentation.

Methods The presentation style of one (almost willing) volunteer was analysed and new presentation

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software was developed to complement the strengths and minimise the weaknesses of this style in order to enhance the delivery of information by the continual stimulation of the audience. Qualitative research methods were applied to proffered audience opinions in order to determine the outcome.

Results Presentation software that enhances the presenter's natural style was found to increase an audience's attention span. A consequence of this was that the material was judged to be of more relevance than it actually was, as indicated by the post-presentation comments received.

Conclusion Whilst ground-breaking research will always keep an audience's attention, work that pushes the boundary can be lost. The marrying of presentation style to presentation software greatly enhances the reception of the subject matter and increases the perceived value of the work undertaken.

Archival Storage Media for Medical Data

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Officially, the term archiving means the transfer of information of public value into a separate repository where it is to be held indefinitely. The requirements for the archiving of medical data vary depending on the context of the information with maternity data having to be retained for a period of 25 years (HSC 1999/053).

There is currently a lack of guidance on the type of media to use for archiving purposes except some very general guidelines from BSI. This guidance covers the Legal Admissibility of Data Stored Electronically and Principles of Good Practice.

However this guidance is not specific to the health service.

When long-term storage is required some of the standard media are not appropriate. Tape storage is a very popular means of data storage, but can suffer very significant errors in the data when stored for a long period, and it is necessary to read and rewrite the data periodically. A long-term, maintenance free medium is required, and there are a number of new possibilities.

This paper examines some useful optical data recording technologies and then compares them for archiving purposes. Arrhenius methods for the determination of the lifetime of data stored on optical media and their development into relevant standards is included, as well as the current guidelines from the relevant bodies such as the Department of Health (DoH) and PacsNet regarding the type of storage media to be used. Following the work a recommendation has been made on the type of media to be used to archive data from a Cardiotachograph Archiving and Surveillance system used in the Labour Ward.

Considerations for Bedside PCs

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Introduction There appears to have been little consideration given to the particular specifications for PCs which are to be placed in the patient environment. The installation of a Cardiotachograph Archiving and Surveillance system in Labour Ward has required us to look carefully at the issues from three standpoints: infection control, electrical safety and patient acceptability.

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Infection Control This issue mostly concerns those parts of the PC which are routinely touched: the keyboard, mouse and, in this case, a touch screen. However all parts of the equipment must be amenable to cleaning in situ, including the interconnection methods. We located and obtained samples of a number of commercially available keyboard and mouse solutions. The cost ranged from £1.60 for a single use cover and from £37 to £426 for sealed keyboards. The products we favour are an IP65 polyester membrane keyboard with integral mouse pad costing £225, two IP68 polyurethane rubber coated keyboards costing £85 and a similarly constructed optical mouse costing £85.

Electrical Safety The interconnected equipment at the bedside must be considered as a whole in the light of IEC60601-1-1. We concluded that both an isolation transformer and a network isolator are required. The reasoning behind this will be presented. Since the application also required a UPS, we procured a medically isolated variant.

Patient Acceptability It is very important that the patient environment is pleasant as well as safe. One problem was the level of fan noise made by some PCs; one PC was rejected on this basis alone. The method of mounting the equipment was chosen to be both ergonomic and unobtrusive in the clinical setting, as well as visually non-threatening from the patient's point of view.

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