White Paper

Comparative Appraisal of the Nepean Emergency Department Information Management System (NEDIMS) versus a Clinical ERP (CERP) system

Introduction, Literature Review, and Methodology

Volume 1

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1. Introduction

Dissatisfaction with large clinical ERP systems (CERP) is widespread with even the best systems labelled the "crème de la krap" by the critics. But critics fail to supply an alternative strategy for large scale health processing tasks such as whole of hospital solutions.

Early CERP systems were targeted at the task of billing for health insurance accounts and only as a secondary objective attempted to solve the needs of clinical information processing. Subsequently, clinicians have been passed hand-me-down solutions that pay lip service to their actual needs and chain them to inefficient and sometimes dangerous systems for many years to come.

As the CERP vendors grew in clientele, the ERP solution has been to characterise the clinical information processing task as one of providing solutions to key point tasks, such as providing the EMR or the more ephemeral EHR. These companies as they have grown have bought out smaller specialist companies producing best-of-breed systems and then integrated their software into the host company's offerings. This has produced supposedly comprehensive software that in fact fails such criteria because: the two software systems are not a good match for each other; the code base is too large and been produced by too diverse a workforce to be cohesive, and maintenance staff are unable to be effective because they do not know enough about the software or the systems. The result is the inability of the CERP provider to adapt their software to new settings, as it should do by definition, either because the new setting is too distant from its current functional base or the programme suite is too complex for their staff to be on top of all the technical details to adapt and maintain the code base for the new clientele. The outcome is a potpourri of code that cannot serve the institutional need in anything but simple and specialised ways and leaves the clinicians in the lurch.

It could be argued that CERP systems in health have reached the limit of their developmental diversity as evidenced by their failure in the UK, [1] Australia [2] and the USA [Z[3]], where installations have been abandoned due to a large overrun in expenditure and failure to deliver anywhere near close to delivery dates and to very substantially under-deliver when roll outs do occur.

If this assertion is true then it should be possible to build a CIS that is more efficient and effective than currently provided implementations. Thus the objective of this investigation is to assess if a newer technology can be devised

1 98 per cent of NPfIT benefits unrealised 7 June 2013. Ehealth Insider. http://www.ehi.co.uk/news/EHI/8647/98-per-cent-npfit-benefits-unrealised
2 Vic govt scraps $500m e-health project,: 18 MAY 2012 Australian Financial Review, http://www.afr.com/p/home/vic_govt_scraps_health_project_ClKImXJ7CJUulFhP16A9GM
3 Waiting for Scot to send a case study

and implemented so as to make a comparative assessment of the CERP system against this hypothetical system.

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2. The Impact of Clinical Information Systems on the Work Place

A good CIS will be intuitive to use and readily adopted by staff as they want better productivity tools, whilst the poor performance of a CIS leads to a process of degradation of confidence in the system going through a series of steps, where each step in the following sequence represents increasing levels of deteriorating morale:

1. Frustration
2. Complacency
3. Avoidance
4. Pervasive Contempt

- **Frustration** leads to compromises in compliance, for example a patient might be sent home without a discharge summary if the system is too slow and clinician feels they should be attending to some else.
- **Complacency** leads to developing workarounds so the system is used less and less and paper methods are gradually brought back into the workflow. Senior staff cannot police this as they are not always around and staff will want to get on with their work.
- **Avoidance** is the structuring of work so that the staff have minimal contact with the CIS. They will always choose a workaround and even do without information to avoid using the CIS. This leads to less information being available in the CIS and therefore less need to use it. At this point the system is decaying.
- **Pervasive** Contempt occurs when staff have got to the point where they deliberately work on the system to demonstrate its weaknesses, such as entering false, ridiculous, and comic information. This is the point of moribundity.

Each stage represents movement into a less satisfactory and more compromised system. As information accumulates in a mixed system of electronic and paper forms, there is a greater risk to patient safety as needed information at the point of decision-making becomes less available and less retrievable. Systems are retained in their moribund state because there is a failure within the organisation to create and sustain a culture of continuous process improvement. If staff do not have the tools and support to analyse their own processes and revise them, the organisation will loose their most creative staff and be reduced entirely to a service organisation of staff standing still in their current activities.

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3. Emergency Department Issues for Clinical Information Systems

Emergency departments operate in conditions that are not matched by other clinical departments, hence the characteristics that must be addressed for an effective solution to their processing needs require investigation.

3.1 The Truisms of Emergency Medicine

> "*The ED is a time pressured environment with ED staff skilled at "cutting corners" to achieve good outcomes in reasonable time, always being aware that they must achieve the greatest good for the greatest number. They understand the opportunity costs of doing one thing over another probably better than any other health care worker. They will readily take up tools that increase their efficiency and make things easier. Anything that decreases their efficiency will cause frustration and will not be used*."
>
> Dr. Rod Bishop, Director ED Services, Nepean Hospital. (2010)

One interpretation of this statement is that reactionism from ED staff is a clear measure of the inadequacy of a CIS. Ignoring such statements is a recipe for disaster.

The key issue then in an ED is the issue of management of time to serve the public, considering:

1. There is always another patient waiting to be attended to.
2. Staff have to work at a pace that is a balance between giving good care to a patient and attending to the next patient.
3. Staff are always attending to multiple patients at any one time.
4. Staff want to get on with their work.

These characteristics make it important that any technology that is introduced into the workplace needs to not only improve the work processes of staff but also not hinder the process compared to what it is replacing. So while technology is often touted as improving patient safety, its value in ED is far more about facilitating the execution of work and supporting improved staff workflow processes.

Hence, if economy of effort is the major criteria in ED for a CIS then it makes sense that this is the toughest possible test for the a CIS technology. In this environment, the things that matter are:

1. The fewest actions to retrieve the information that is wanted.

2. An intuitive interface to minimise training effort - the "Current Staff Usability Test" - Ideally a current staff member should need no more that 4 minutes training.
3. Intrinsic encapsulation of workflow. The software should lead the user though the workflow. It should prevent actions when there is a lack in content. It should direct to the next act of information solicitation when something is complete. It should alert when something is fishy or dangerous. And it should allow for all these thing to be specified in the design process.

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4. Literature Survey

The literature for this study has to be pertinent to a wide range of matters, including:

The use of CISs in EDs;
The design, construction and deployment of CISs;
The use of workarounds with CISs and work processes generally.

The review has been organised around both topics and the types of studies provided by the authors, namely:

Advocacy and Review Papers
Before and After Assessments
In Vivo Assessments
Post implementation studies
The Comparison of CISs
Concept Papers
Usability Studies

The literature on EMRs and CISs is extensive generally but there are significant gaps in certain research areas relevant to this study. It was particularly difficult to find articles on the live assessments of emergency department systems, and there is little work on comparative analysis of two electronic systems and appropriate methodologies for completing that work. The survey has coverage of a range of topics that were relevant to the conducted study with other less relevant material such as CPOE touched on very lightly if at all.

4.1 Advocacy and Review Papers

An AHRQ [2010][4] report defined a vision of an ideal health care delivery system in the following statement, reproduced here in full:

> "The emphasis is on (the vision of) a system that is *new*, *patient-centered*, and *engineered*:
>
> (1) The new, redesigned system is integrated, ubiquitous, distributed, responsive, expansive, flexible, and resilient.
>
> (2) Delivery of health care is personalized, facilitated by secure

[4] Valdez RS, Ramly E, Brennan PF. Industrial and Systems Engineering and Health Care: Critical Areas of Research--Final Report. (Prepared by Professional and Scientific Associates under Contract No. 290-09-00027U.) AHRQ Publication No. 10-0079. Rockville, MD: Agency for Healthcare Research and Quality. May 2010.

[4] 14. Taylor TB. Information management in the emergency department. Emerg Med Clin North Am. 2004 Feb;22(1):241-57.

information flow, and mindful of patient privacy. Transparency and open access enable people to make informed choices about their health, with a focus on prevention and health promotion.

(3) The delivery system is information-optimized and runs smoothly, efficiently, and safely.

All stakeholders leverage ISYE and information and communication technologies to drive both subsystem and system-wide changes. Incentives are aligned to enhance quality of life for all, at the individual and population levels. Evidence-based analytics and mathematical modelling inform standard care processes and biomedical knowledge discovery."

Other technology promotional papers such as Taylor [2004][14][5] which advocate reproducing well-known defective processes and enterprise wide integrated solutions with real-time analytics fail to provide tangible guidance on defining optimal processes and operational methods. Gordon [2004] [15][6] also made an advocacy case for online analytical processing (OLAP) as software to make care improvement in the ED.

Beauscart-Zephir et al [2007] [23][7] claim that usability flaws have been uncovered in healthcare and that many procurement and implementation processes ignore human factors issues. They make the strong claim that this results in potentially dangerous and always unpleasant work situations. They recommend the Human Factors Engineering should always be applied to healthcare products and that each product "should be systematically checked before permitting their release and implementation".

In the most recent review by Staggers et al [2013] [24][8] they identify 5 issues in usability in an attempt to debunk objections to addressing usability issues and they claim that it is not acceptable to make these assertions "(1) usability only concerns the look and feel of a product and is, therefore, only a minor concern, (2) usability is not measurable, (3) usability stifles innovation, (4) vendors are solely responsible for product usability, and (5) usability methods are not practical for use in healthcare."

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[5] 15. Gordon BD. Asplin BR. Using online analytical processing to manage emergency department operations. Acad [5] 15.

[6] 15. Gordon BD. Asplin BR. Using online analytical processing to manage emergency department operations. Acad Feb;22(1):241-57.

[7] 23. M.-C. Beuscart-Zéphir, Peter Elkin, Sylvia Pelayo, Regis Beuscart. The Human Factors Engineering Approach to Biomedical Informatics Projects: State of the Art, Results, Benefits and Challenges. IMIA Yearbook 2007: Biomedical Inform. for Sustainable Health Systems.

[8] 24. N. Staggers, Y. Xiao, L. Chapman. Debunking Health IT Usability Myths. Invited Editorial. Applied Clinical Informatics, Vol. 4: Issue 2 2013, pp. 241-250.

Farley et al [2013][9] have made a study of a range of ED systems and produced a set of recommendations of problems with such systems. They set out to provide four exemplar case studies of problems using CISs in EDs, labelled EDISs, and the consequences they have for patient safety. Their cases studied a number of safety concerns including: communication failure, wrong order–wrong patient errors, poor data display, and alert fatigue. From the lessons learnt in the scenarios they constructed a list of 4 end-user oriented and 3 vendor orientated recommendations for improving the operational efficiency of the EDISs and the patient safety.

These recommendations include:

1. ensuring that emergency providers actively participate in selection of the EDIS product,
2. in the design of processes related to EDIS implementation and optimization, and
3. in the monitoring of the system's ongoing success or failure.

Whilst the relevance of their recommendations generally to ED operations is unquestionable, the pertinence to the Australian setting is open to discussion:

1. *End-User Recommendation 1: A local ED clinician champion should be appointed to maintain a performance improvement process for the EDIS and lead the EDIS performance improvement group.*
   In our experience the ED directors had a view that continuous process improvement was an intrinsic part of their job description and had senior colleagues who supported this outlook.

2. *End-User Recommendation 2: A multidisciplinary EDIS performance improvement group should meet regularly and communicate regularly with ED and hospital leadership.*
   We have not come across such formal structures but staff are certainly on top of the issues of the effect of IT on their work and the interaction of their processes with other parts of the hospital and vice versa.

3. *End-User Recommendation 3: A review process should be in place to monitor ongoing patient safety issues with the EDIS. ED providers and other stakeholders should be encouraged to submit safety concerns for review. In addition, prospective risk assessments should be conducted regularly*.
   Once again we have not seen evidence for such a formal approach but consciousness of safety issues have always seemed paramount to any

[9] Heather L. Farley, Kevin M. Baumlin, Azita G. Hamedani, Dickson S. Cheung, Michael R. Edwards, Drew C. Fuller, Nicholas Genes, Richard T. Griffey, John J. Kelly, James C. McClay, Jeff Nielson, Michael P. Phelan, Jason S. Shapiro, Suzanne Stone-Griffith, Jesse M. Pines. Quality and Safety Implications of Emergency Department Information Systems. published online 24 June 2013. http://www.annemergmed.com/article/S0196-0644(13)00506-4/abstract

group we have worked with. Generally reporting process to do with IT have been considered dysfunctional by clinical staff to the extent that many do not bother with making reports when they identify problems but rather focus on designing workarounds.

4. *End-User Recommendation 4: EDIS-related patient safety concerns identified by the review process should be addressed in a timely manner by ED providers, the EDIS vendors, and hospital administration. Each of these processes should be performed in full transparency, specifically with openness, communication, and accountability.*
   Each ED will have its own methods for capturing patient safety concerns and will broadcast them staff in through their standing mechanisms. Solutions will generally be driven by a need to workaround the IT to get the best outcomes.

5. *Vendor Recommendation 1: Lessons learned from performance improvement efforts should be measured and shared publicly, including with other EDs using the same EDIS.*
   Many vendors have User groups through which they encourage the sharing of experiences.

6. *Vendor Recommendation 2: EDIS vendors should learn from local patient safety improvements and ensure timely distribution of necessary changes to all installation sites.*
   The experiences amongst the EDs we have worked with indicate there is no effective interest by the vendor in learning about patient safety improvements and changing the software to introduce these types of enhancements.

7. *Vendor Recommendation 3: "Hold harmless" or "learned intermediary" clauses should be removed from vendor software contracts.*
   This has not been identified as pertinent at the level of ED management to our knowledge at least in part because as stated in point 3 above staff have lost belief that anything can be changed.

Unfortunately, these recommendations are all high level proposals that only inform us about the issues with EDISs at a general operational level and do little to provide clear guidelines at the EDIS design level. The authors do point to crucial issues as to the effect of EDISs on staff in saying that "Variation in EDIS functionality affects physician decision making, clinician workflow, communication, and, ultimately, the overall quality of care and patient safety in a particularly challenging clinical environment (e.g. high volume, time sensitive)." They also point out that this situation is further variable due to new demands from clinicians, administrators and government. Hence they propose that EDIS should be flexible enough to be modified at the user level while uniform enough to encourage best practice.

The authors point out that there is a growing body of evidence that many EDIS-related errors are due more to poor design than user inexperience and lack of

training. Hence they argue that EDISs should not only be designed to match common properties of human perception as defined by the HCI discipline but also satisfy "task- and user specific properties of work".

More specific complaints about the suability features of EDISs are: poor data display such as: long unmanaged lists of results with better identification of abnormal results needed; creating the wrong order for the wrong patients because of poor screen presentation of the patient whose record is being viewed, inadequate separation of like-named patients and overreliance of alert mechanisms; elimination of trivial alerts to reduce alert fatigue.

A paper by Karsh et al [2010][10] lays out a list of 10 fallacies about Health IT and how they cause a disservice to achieving better quality systems. The fallacies are discussed below:

1. HIT is risk free leads to a lack of appreciation that HIT will have failure modes of many types which in the limit can introduce changes to clinician daily work that is faulty. Once such faults are identified they become the target points for workarounds but they may prove to be fatal before their inadequacy is identified.

2. The fallacious belief that HIT is not a medical device has lead to it evading the same scrutiny not available to more conventional devices despite it having potentially the same impact on patient care.

3. The learned intermediary principle presents the HIT as faultless and the user the sole arbiter of errors, hence the user is accountable for all errors. The authors position how this in fact contradicts the argument that HIT will reduce human errors but humans will have to catch HIT errors.

4. The "use equals success fallacy" is perhaps the most common of HIT staff misconceptions. In this mental space failures are due to poor training or poor attention by clinicians. The authors point to many studies that show system malfunctions are typically a combination of many factors throughout the whole social mélange of organisations ranging from the clinical department up to governmental administration but including a variety of issues based on psychology, work practices, safety science, social psychology and systems engineering.

5. The "messy desk" fallacy defines clinical work as requiring linearized processes to make it work efficiently and eliminate the messy desk. This is a failure to recognise the mosaic of processes that have to be managed by

[10] BT Karsh, M B Weinger, P A Abbott, R L Wears. Health information technology: fallacies and sober realities. *J Am Med Inform Assoc* 2010;17:617-623 doi:10.1136/jamia.2010.005637

staff due to the inherent variability of patient conditions and attention needs. HIT needs to be designed so that the inherent variation in work processes are facilitated rather than eliminated.

6. The "father knows best " fallacy is the strategy to adopt HIT systems that optimises the upstream benefits to administrators and profit centres rather than the users who do the work. A system not optimised to the advantage of the users fail the first usability test and a requirement that enforces documentation above care will always be worked around or create greater inefficiencies than it resolves.

7. The "Field of Dreams" fallacy is the belief by the designer that the failure of a system is due to the users being uncooperative. This is also known as "designer centred design". When the authority to design the work process is passed to the designer then the users are coerced into working with something that does not match their needs in which case they fail to co-operate. "Cognitive support that offers "clinicians and patients assistance for thinking about and solving problems related to specific instances of healthcare" is the area where the power of IT should be focused."

8. The belief that "one size fits all" ignores the fact that modern medicine is practiced much more as a team of staff with different but interacting tasks. HIT needs to facilitate the differences and their interactions.

9. The "paperless office" principle shows a lack of appreciation of the advantages of paper and why staff will persist in using it. The paper form carries a great deal of contextual characteristics that are lost by the reductionism created by typical HIT implementations of the same content in different ways. Studies have shown that "User-created paper artefacts typically support patient-specific cognition, situational awareness, task and information communication, and coordination, all essential to safe quality patient care."

10. The fallacy that "no-one else understands healthcare" leads to alienation between designers and clinicians. Successful HIT will come about by closely co-ordinated studies of clinical work processes by designers and reliable feedback from clinicians about what works and what does not. Clinicians do not know necessarily know what will work best for them as much as designers do not know either. The real productive systems will emerge out of the close co-operation of the two groups.

In summary, the authors say "The needs of users and the complexities of clinical work must be analysed first, followed by evaluation of the entire scope of potential solutions, rather than examining the current array of available products and characterizing the needs that they might meet".

In a statement about how to understand the effectiveness of HIT the authors state "use may not truly be meaningful in a clinical sense until HIT truly supports users' needs. During HIT development, vendors and healthcare organizations must focus on more meaningful measures of design success: clinician and patient ease of learning, time to find information, time to solve relevant clinical problems, use errors, accuracy of found information, changes in task and information flow, workload, situation awareness, communication and coordination effectiveness, and patient and clinician satisfaction. These measures should be applied to all members of the care team." We would note that the authors have failed to acknowledge another critical characteristic of all these measurables in that, they need to be understood as relative measures between systems, solutions or tasks. There is no meaningfulness in any absolute value for any of them.

Perhaps the best brief assessment of the needs of computerised systems was expressed very early in the history of health informatics which Octo Barnett delivered in 1970 [1995][11] in his 10 commandments for system behaviour:

1. Thou shall know what you want to do

2. Thou shall construct modular systems - given chaotic nature of hospitals

3. Thou shall build a computer system that can evolve in a graceful fashion

4. Thou shall build a system that allows easy and rapid programming development and modification

5. Thou shall build a system that has consistently rapid response time and is easy for the non-computernik to use

6. Thou shall have duplicate hardware systems

7. Thou shall build and implement your system in a joint effort with real users in a real situation with real problems

8. Thou shall be concerned with realities of the cost and projected benefit of the computer system

9. Innovation in computer technology is not enough; there must be a commitment to the potentials of radical change in other aspects of healthcare delivery, particularly those having to do with organization and manpower utilization

10. Be optimistic about the future, supportive of good work that is being done, passionate in your commitment, but always guided by a fundamental

[11] Morris Collen . A History of Medical Informatics in the United States 1950-1990, American Medical Informatics Assn; 1st edition, 1995 pp 168-169.

skepticism.

Many of these criteria are more important than ever in today's technology developments and will be seen to be reemphasised in the subsequent system designs developed in this report.

4.2 Before and After Assessments

Process redesign at Mount Sinai Medical Centre reported by Baumlin et al [2010][16a][12] brought about by the introduction of an EDIS showed a statistically significant reduction in length of stay, doctor to disposition time, door to doctor time, X-ray turnaround time, CT scan time, and lab times. Overall the results showed improved ED efficiency. In an extension of this study Shapiro et al [2010] [16b][13] showed that there was increased net revenue over costs that meant that ROI was achieved in 8 months

Vartak et al [2009] [17][14] report that there was a significant increase in the length of stay in the ED after implementation of EHR, CPOE and event tracking systems. Asro and Banet [2004][18][15] showed in a study of the introduction of CPOE and Nursing documentation that time spent on direct patient care did not change but the time spent on computers increased with a concomitant decrease in time spent on paper. These indicates neutral effect on ED efficiency.

Banet et al [2006][19][16] added to this study with another report that reported nurses subjective evaluation of the CPOE and documentation system as being more efficient by requiring less time for orders despite objective measures showing no change. Nurses with greater computing experience reported using more template options suggesting this expertise was necessary to maximize the gains to be gotten from computerization.

In Yen [2009] [21][17] a series of observation were made of caregivers' time allocation before and after the introduction of CPOE in a paediatric emergency department. The results indicate that physicians increased their time on the

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[12] 16a. Baumlin KM, Shapiro JS, Weiner C, Gottlieb B, Chawla N, Richardson LD. Clinical information system and process redesign improves emergency department efficiency. Jt Comm J Qual Patient Saf. 2010 Apr;36(4):179-85.

[13] 16b. Jason S. Shapiro, Kevin M. Baumlin, Neal Chawla, Nicholas Genes, James Godbold, Fen Ye, and Lynne D. Richardson. Emergency Department Information System Implementation and Process Redesign Result in Rapid and Sustained Financial Enhancement at a Large Academic Center. ACADEMIC EMERGENCY MEDICINE 2010; 17:527–535 [a] 2010. doi: 10.1111/j.1553-2712.2010.00720.x

[14] 17. Vartak S. Crandall DK, Brokel JM, Wakefield DS, Ward MM. Transformation of Emergency Department processes of care with EHR, CPOE, and ER event tracking systems. HIM J. 2009;38(2):27-32.

[15] 18. Asaro P, Banet G. The effect of physician order entry and computerized nursing documentation on how emergency department providers spend their time. Ann Emerg Med. 2004;44:S30.

[16] 19. Banet GA, Jeffe DB, Willimas JA, Asaro PV. Effects of implementing computerized practitioner order entry and nursing documentation on nursing workflow in an emergency department. J Healthc Inf Manag. 2006 Spring;20(2):45-54.

[17] 21. Yen K, Shane EL, Pawar SS, Schwendel ND, Zimmanck RJ, Gorelick MH. Time motion study in a pediatric emergency department before and after computer physician order entry. Ann Emerg Med. 2009 Apr;53(4):462-468.e1. doi: 10.1016/j.annemergmed.2008.09.018. Epub 2008 Nov 20.

computer by the order of 50% while nurses had no change in patient contact but decreased their amount of time talking to other staff about patients.

Bisantz et al (2010)[18] describe an assessment on the information recorded on patient status boards before the introduction of an EMR system with its electronic replacement. While categories of content were shown to be relatively equivalent, the frequencies at which some types of information appeared on the two displays was often dissimilar, in particular, "information used to coordinate aspects of patient treatment was more frequently found in the manual system." This was seen as evidence that it was not sufficient for electronic replacements of the status boards to simply match format or types of information fields as it would not necessarily sustain the current work practices and lead to unintended changes in usage. Two early study by Wears and Perry (2007)[19] and Wears et al (2003)[20] foreshadowed this observation from a study on the use of such boards in A&E departments which showed the identification of latent properties at risk of loss in a computerised version of the utility functions of the boards.

One retrospective study was conducted comparing the performance of an ED before an after the introduction of Firstnet. This study is particularly relevant for this research as it was conducted at Nepean Hospital, Sydney, where this research project was subsequently executed. The study involved an analysis of the performance statistics of the department for a 6 month period prior to the introduction of Firstnet to a 6 month period after this introduction (Mohan, Bishop, Mallows (2013)[21]. The findings state "There was a statistically significant increase in the waiting time, treatment time and total time spent in ED for the discharged patients after the introduction of Cerner FirstNet compared to the control period. There was a statistically significant increase in the patients who did not wait to see a doctor and in the proportion of ambulances offloaded in greater than 30 min. There was also a decrease in the average number of patients seen per doctor shift. These findings indicate deterioration in the performance of the ED after the implementation of Cerner FirstNet."

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[18] Bisantz, A. M., Pennathur, P., Guarrera, T. K., Fairbanks, R. J., Perry, S. J., Zwemer, F., & Wears, R. L. (2010). Emergency department status boards: A case study in information systems transition. Journal of Cognitive Engineering and Decision Making, 4(1), 39 - 68.

[19] Wears, R. L., & Perry, S. (2007). Status boards in accident and emergency departments: support for shared cognition. Theoretical Issues in Ergonomics Science, 8(5), 371 - 380.

[20] Wears, R. L., Perry, S., Shapiro, M., & al., E. (2003). A comparison of manual and electronic status boards in the emergency department: What's gained and what's lost? Proceedings of the Human factors and Ergonomics Society 47th Annual Meeting. (pp. 1415 - 1419). Santa Monica, CA: Human Factors and Ergonomics Society.

[21] Mohan MK, Bishop RO, Mallows JL. Effect of an electronic medical record information system on emergency department performance. Med J Aust 2013; 198: 201-204.

4.3 In Vivo Assessments

In one of the few in vivo experiments in two French teaching hospitals reported by Carton et al [2002] [21][22] staff were provided advice on the computer screen for radiology orders. Whilst the comparison between the trial group and control group (with no advice) showed reduction of orders that fell outside guidelines the most valuable learning was that trainees were responsible for 70% of the non-conforming referrals. This study shows that discovery of ways to improve processes comes about from the detailed analysis of the processes of the individual departments.

Mayer et al [2010] [21b] [23]performed an in vivo study of the effect of using an EDIS on LOS by interns. Over a one month period the "learning curve effect" for new interns showed no decrease in patient LOS.

Connelly et al (2012)[24] in a revision of a study by Theera-Ampornpunt (2009)[25] studied the effect of the EMR on the length of stay (LOS) of patients in the ED. They showed that the EMR contributed to increasing the LOS in one hospital and decreased it for two hospitals. The cause for these differences was not identified.

4.4 Post implementation studies

Park and Chen [2012] [22][26] study an ED after the introduction of an EMR identified workarounds as a process of post implementation design process and argues that participatory design did not adequately engage clinicians in the design process, Their engagement was further limited by the effect of interference of the "symmetry of ignorance", that is the lack of design knowledge made it difficult for them to participate in the design process. However as the deployed system impacted their work processes they became "invisible designers" working to redesign their system.

"One of the prominent observations from the study was that the workarounds initiated by clinicians were primarily used to accommodate the complexity of ED

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[22] 21. Matthieu Carton, Bertran Auvert, Henri Guerini, Jean-Christophe Boulard, Jean-Francois Heautot, Marie-France Landre, Alain Beauchet, Marc Sznajderi, Dominique Brun-Ney, Sophie Chagnon. (2002). Assessment of radiological referral practice and effect of computer-based guidelines on radiological requests in two emergency departments. Clin Radiol. 2002 Feb ;57 (2):123-8.

[23] Paula H. Mayer, Michael Yaron, and Steven R. Lowenstein. Impact on Length of Stay After Introduction of Emergency Department Information System. West J Emerg Med. 2010 September; 11(4): 329–332.

[24] Donald P Connelly, Young-Taek Park, Jing Du, Nawanan Theera-Ampornpunt, Bradley D Gordon, Barry A Bershow, Raymond A Gensinger Jr, Michael Shrift, Daniel T Routhe, Stuart M Speedie. The impact of electronic health records on care of heart failure patients in the emergency room. J Am Med Inform Assoc 2012;19:334-340. doi: 10.1136/amiajnl-2011-000271. published online November 9, 2011.

[25] Nawanan Theera-Ampornpunt, Stuart M. Speedie, Jing Du, Young-Taek Park, Boonchai Kijsanayotin, and Donald P. Connelly. Impact of Prior Clinical Information in an EHR on Care Outcomes of Emergency Patients. AMIA Annu Symp Proc. 2009; 2009: 634–638. Published online 2009 November 14.

[26] [22] Sun Young Park, Yunan Chen. Adaptation as Design: Learning from an EMR Deployment Study. CHI 2012, May 5–10, 2012, Austin, Texas, USA.

work practice in the socio-technical system."

The authors argued that the generality of the EMR was insufficient to be efficient in the local workplace and so recommended the adaptation of the EMR "into local practices is critical yet it was insufficiently considered in the original design. Therefore, we suggest that design practices envision ED as a complex, socio-technical system that encompasses the practices surrounding all the artefacts, stakeholders types of patient care, spatial layout, existing technological use, and the clinical workflow of the local site, as well as shared information systems." Thy conclude that the richest learnings for the design in the transition period of bedding in the system when the end-users are negotiating use of the system and actively designing their workarounds.

A study by Callen et al (2013)[27] [ ] was a post implementation survey of 96 clinical staff in 4 Emergency departments in NSW, Australia. They found that staff identified advantages for an enterprise ED system (Cerner FirstNet) to have direct access to orders, pathology and radiology services but that a wide range of usability issues were serious impediments to achieving any practical level of efficiency in work practices.

4.5 Comparison Studies – CPOE

Less relevant to this project is CPOE studies in ED. A major study of CPOE usage has recently been published by Georgiou (2013)[28] which reviews the current state of the efficacy and usability of these systems. They point out that there have been only 22 published studies of actual operational usage of such systems. The findings from these studies are ambiguous as to key issues of usability and comparative evaluation.

Murf and Kannry [2001] [30][29] completed a comparison of staff satisfaction with two CPOE systems and showed significantly higher satisfaction for a Veterans Affairs system developed in-house compared to a commercially available system. Thus they established that not all systems could be considered equal and design issues were critical to staff acceptance of such systems. Their study gives a great deal of attention to the perceived efficiency of a system and showed that high efficiency correlated with high satisfaction scores. There also

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[27] Joanne Callen, Richard Paoloni, Julie Li, Michael Stewart, Kathryn Gibson, Andrew Georgiou. Perceptions of the Effect of Information and Communication Technology on the Quality of Care Delivered in Emergency Departments: A Cross-Site Qualitative Study. Ann Emerg Med. 2013;61:131-144. http://dx.doi.org/10.1016/j.annemergmed.2012.08.032

[28] 35. Andrew Georgiou, Mirela Prgomet, Richard Paoloni, Nerida Creswick, Antonia Hordern, Scott Walter, Johanna Westbrook.
The Effect of Computerized Provider Order Entry Systems on Clinical Care and Work Processes in Emergency Departments: A Systematic Review of the Quantitative Literature
Annals of Emergency Medicine Volume xx, □□. x : Month □□□□.

[29] 30. H Murf, Joseph Kannry. Physician satisfaction with two order entry systems. JAMIA, 8, 5, 2001. 299-509. http://jamia.bmj.com/content/8/5/499.full.pdf+html Accessed 30th May 2013.

noted that this was a constant finding over a number preceding studies in the 1990s.

A study by Rainu et al [2011] [31][30] compared a best-of-breed CPOE system used by 6 practices with an enterprise CPOE system used by 5 practices. They found that after adjusting for baseline differences, the best-of breed users had a 4-fold lower rate of errors after 1 year of usage. They concluded that despite improved workflow integration, the enterprise e-prescribing application performed less efficiently than the best-of-breed system.

A study by Westbrook [2012] [32][31] also compared two different commercial CPOE installations at wards in two hospitals and found that error rate was reduced significantly relative to control wards that did not use the CPOE.

Asaro et al [2006] [33][32] explored where an assessment was made of the effect of an EDIS on adherence to a coronary guideline which did not improve with implementation The authors argued that the lack of patient-specific decision-support functionality hampers progress in clinical use of decision support.

An extension of this work by Asaro and Boxerman [2008] [34][33] showed that while a CPOE system shifted nurses from working with paper to the computer it did not significantly changed their time with patients. On the other hand physicians showed a substantial shift in time with nurses and patients to retrieving information from the computer. It was observed in the study that the largest change in behaviour was the change in planning with computer acting as the mediating agent for both physician and nurse and in the case of physician reducing patient contact. This indicates that the changes are not only the changes due to the CPOE system itself but also the participant self-selecting changes and to consider how they effect the overall medical service.

A retrospective study by Spalding et al (2011)[34] demonstrated in a study comparing LOS before and after the introduction of CPOE that the LOS decreased for discharged patients and increased for admitted patients.

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[30] 31. Rainu Kaushal, Yolanda Barron, and Erika L. Abramson. The Comparative Effectiveness of 2 Electronic Prescribing Systems. Published Online: December 16, 2011. Accessed 30th May, 2013. http://www.ajmc.com/publications/issue/2011/2011-12-vol17-SP/The-Comparative-Effectiveness-of-2-Electronic-Prescribing-Systems.

[31] 32. Westbrook JI, Reckmann M, Li L, Runciman WB, Burke R, et al. (2012) Effects of Two Commercial Electronic Prescribing Systems on Prescribing Error Rates in Hospital In-Patients: A Before and After Study. PLoS Med 9(1): e1001164. doi:10.1371/journal.pmed.1001164. http://www.plosmedicine.org/article/info%3Adoi%2F10.1371%2Fjournal.pmed.1001164

[32] 33. Phillip V. Asaro, Amy L. Sheldahl, Douglas M. Char. Embedded Guideline Information without Patient Specificity in a Commercial Emergency Department Computerized Order-entry System. ACADEMIC EMERGENCY MEDICINE 2006; 13:452–458.

[33] 34. Phillip V. Asaro, Stuart B. Boxerman. Effects of Computerized Provider Order Entry and Nursing Documentation on Workflow. 2008. Academic Emergency Medicine. Vol 15, No. 10, 908-915. doi: 10.1111/j.1553-2712.2008.00235.x

[34] Spalding SC, Mayer PH, Ginde AA, Lowenstein SR, Yaron M. Impact of computerized physician order entry on ED patient length of stay. Am J Emerg Med. 2011 Feb;29(2):207-11. doi: 10.1016/j.ajem.2009.10.007. Epub 2010 Mar 26.

4.6 Concept Papers

Sinsky et al (2012)[35] published a discussion paper on methods for reporting user experiences of Health IT products. The identified methods for measuring and reporting users experience with HIT of: Laboratory experimentation using simulations, point of use testing, data mining of usage statistics "behind the scenes", surveys of users, and formal hazard reporting systems. They advocate that product review should use multiple modalities to fully explore all the issues of usability of a system where, for example, a user survey may uncover safety hazards recognised by users it will not uncover hazards they do not recognise.

The advantage of Flight Simulator testing is that common scenarios can be tested across multiple vendors. Point-of-Use reporting is the idea of users being able to click a "report here" button and write a report of their issues. This could enable a significant volume of materials to be collected about usability and identify common issues. The idea of Data Mining studies is the collect time and clicks data by users without intruding on their work. This data could point to inefficiencies in design.

The paper describes a number of barriers to reporting faults through the whole pathway of clinicians discovering faults through their own organisations and then through the vendors organisation and so they advocate a pathway to direct public reporting of faults to a website run by a trusted government organisation. In summary they have the goal of collecting and publicly reporting on user experiences to improve products across the industry.

This approach is admirable in the face of the current enterprise approach to creating software and organisation wide solutions of generic electronic medical records. However we will argue that this approach concedes to an architecture that is of itself faulty and if corrected a number of issues important to this solution will diminish significantly.

4.7 Usability Issues - User Interfaces

A study of the user interface of the AHLTA (Armed Forces Health Longitudinal Technology Application) was analysed using the Cognitive Task Analysis (CTA) method called GOMS (Goals, Operators, Methods, and Selection rules) and an associated technique called KLM (Keystroke Level Model) (Saitwal et al, 2009).[36]They identified that the AHLTA system had a large number of steps to complete common tasks but showed no revisions of the system to demonstrate that it

[35] Christine A. Sinsky, Jason Hess, Ben-Tzion Karsh, James P. Keller, and Ross Koppel. Comparative User Experiences of Health IT Products: How User Experiences Would Be Reported and Used. September 2012. Institute of Medicine.

[36] Himali Saitwal, Xuan Feng, Muhammad Walji, Vimla Patel, Jiajie Zhan. Assessing performance of an Electronic Health Record (EHR) using Cognitive Task Analysis. Published online 10 May 2010. International Journal of Medical Informatics Volume 79, Issue 7 , Pages 501-506, July 2010. http://www.ijmijournal.com/article/S1386-5056(10)00074-2/abstract. Accessed 30-05-2013.

could be improved. They asserted the interface needed to be improved by reducing the total number of steps and the amount of mental effort required for the tasks without attempting to do the same or explaining how these changes could be achieved.

An alternative to understanding usability performance was a survey conducted by Bundschuh et al (2011) 37 in German hospitals. A questionnaire about clinical information systems was provided through a web page which was answered by 1003 people from 158 hospitals. It focused on "suitability for task, training effort and conformity with user expectations, differentiated by information systems. Effectiveness was evaluated with the focus on interoperability and functionality of different IT systems". The analysis indicated that there was a greater preference for information systems with a higher level of customisation particularly in specialised settings, that is a preference for best-of-breed systems. Generic systems that were intended for many and varied tasks showed a lower preferences indicating the greater difficulty in creating good user interfaces for such systems.

In another survey study by Batley (2011)[38] a successful implementation of an "ED Dashboard" was the basis of survey of 175 out 188 end-users. Some 93% of users perceived the system was easy or extremely easy to use. The design features of note were "being alerted when new test results were ready, the use of "most common" lists, and the use of colour were features that were considered valuable to users". The success of the system was attributed to the careful attention to detail of system design.

A literature review by Peute et al (2008)[39] covering publications from 1990-2006 identified 52 papers of interest. Their analysis showed that most studies presented summative usability results on working systems which focused on the adoption problems of systems. Formative usability studies lacked a systematic approach to describing the manner in which study results contributed to the iterative development cycle of systems.

The usability of a US military EHR, AHLTA, was studied by Zhang et al (2009)[40] using a work centred evaluation framework: User, Functional, Representational

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[37] Bundschuh BB, Majeed RW, Bürkle T, Kuhn K, Sax U, Seggewies C, Vosseler C, Röhrig R. Quality of human-computer interaction--results of a national usability survey of hospital-IT in Germany. BMC Med Inform Decis Mak. 2011 Nov 9;11:69.

[38] Batley NJ, Osman HO, Kazzi AA, Musallam KM. Implementation of an emergency department computer system: Design features that users value. J Emerg Med. 2011 Dec;41(6):693-700. doi: 10.1016/j.jemermed.2010.05.014. Epub 2010 Jul 9.

[39] Peute LW, Spithoven R, Bakker PJ, Jaspers MW. Usability studies on interactive health information systems; where do we stand? Stud Health Technol Inform. 2008;136:327-32.

[40] Zhen Zhang, Muhummad F Walji, Vimla L. Patel, Ronald W. Gimbel, and Jiajie Zhang. Functional Analysis of Interfaces in U.S. Military Electronic Health Record System using UFuRT Framework. AMIA Annu Symp Proc. 2009; 2009: 730–734. Published online 2009 November 14.

and Task Analysis (UFuRT). The study concentrated on the Task Analysis process which classified all interface objects into either Operations or Objects. Operations making up 61% of 1996 interface artefacts were further classified in Domain or Overhead classes the latter of which was about 25% of the sample. The identification of overhead functions created a focus for improvements to the usability of the system.

A study by Singh et al [2013][41] investigated the relationship between missed test results and information overload. While the study was using Primary Care Providers it is of interest due to the investigation model. The aim was to use an 8-dimensional socio-technical model representing multiple facets of EHR-based test results notification. The dimensions were technological factors: EHR notification software, its case of use, content of alerts and EHR user interface; and social factors: workflow, people, organisational policies, and procedures. The study showed that 70% of PCP perceived that they received more alerts than they could handle but the broader investigative model suggested that it would not be enough just to reduce the number of alerts to improve their performance to recognise abnormal results. Rather, the information overload came from not only the number of alerts but electronic handover in care and poor EHR usability.

In vivo studies for usability are less frequent due to the difficulties caused by interrupting work processes in live settings. More common are surveys and laboratory based determinations. A qualitative study by Lapointe and Rivard [2004][42] of 3 hospitals argues that usability was a key factor in early use of the system but that political factors in power sharing became important as battles between nurses and doctors as work responsibilities were altered. In one hospital a culture of collaboration and a determination to not disturb power arrangements achieved much more successful implementation. In particular there was detail applied to management processes to ensure department heads had leadership roles, clinician champions were recruited, problems were addressed quickly, physicians were actively involved in processes and co-ordination mechanisms activated.

The National Institute for Standards and Technology (NIST) has produced an extensive range of materials on usability. These guides to usability have lengthy recitals of the many issues that are pertinent to good usability in the design of CISs and list a wide range of processes and methods of testing for usability. The key elements of Usability are Effectiveness, Efficiency and Satisfaction [1998][43].

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[41] Hardeep Singh, Christiane Spitzmueller, Nancy J. Petersen, Mona K. Sawhney, Dean F. Sittig. Information Overload and Missed Test Results in Electronic Health Record–Based Settings. *JAMA Intern Med.* 2013;():1-3. doi:10.1001/2013.jamainternmed.61. Published online March 4, 2013.

[42] [13] Lapointe L, and Rivard S. (2004). Clinical Information systems: Understanding and preventing their premature demise. HEC Montreal. ISSN 1702-238X. Articles on Comparisons of CIS.

[43] ISO 9241-11. Ergonomic requirements for office work with visual display terminals (VTDs) – Guidance on usability.

Effectiveness is the extent to which a CIS fulfils the tasks a user wishes to perform. Efficiency is the speed at which they can perform these tasks, and Satisfaction is the subjective experience of the user in working in the system.

The NIST (NISTIR 7741)[44] report details a review of the literature with the aim of demonstrating that usability has been recommended in a number of studies by HIMSS[45] and AHRQ[46] [47] [48] to be a key factor retarding the take up of electronic record keeping by physicians[49] and point to studies[50] and newspaper articles[51] [52] [53] identifying case studies on major failures. There seems little doubt that there is a widespread opinion that usability is a key issue in creating good HIT[54] but there are still many hurdles to overcome to attain this desirable goal.

The NIST has invested heavily in defining usability for the "EHR" with many publications on the topic. In essence their reports advocate for a User Centred Design (UCD) approach were the technology development team works with selected clinicians to define a desirable system and then for the technologists to control the construction of the system with regular iterations driven by testing processes with selected users and other non-users recruited for testing. This approach has been developed over many years of development of Usability Principles and in some ways is conventional wisdom for that community. This view has been revised more recently to give a more detailed analysis of usability (NISTIR 7804)[55]. While we agree with a great deal of the content of these reports there are a number of issues that our methodology varies from their

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[44] 2. Robert M. Schumacher, Svetlana Z. Lowry. NIST Guide to the Processes Approach for Improving the Usability of Electronic Health Records. NISTIR 7741. November 2010

[45] 3. Belden J, Grayson R, Barnes J. *Defining and Testing EMR Usability: Principles and Proposed Methods of EMR Usability Evaluation and Rating*. Healthcare Information Management and Systems Society Electronic Health Record Usability Task Force. Available at: http://www.himss.org/content/files/HIMSS_DefiningandTestingEMRUsability.pdf Accessed June 2009.

[46] 4. Armijo D, McDonnell C, Werner K. (2009a) *Electronic Health Record Usability: Interface Design Considerations.* AHRQ Publication No. 09(10)-0091-2-EF. Rockville, MD: Agency for Healthcare Research and Quality. October 2009.

[47] 5. Armijo D, McDonnell C, Werner K. (2009b). *Electronic Health Record Usability: Evaluation and Use Case Framework.* AHRQ Publication No. 09(10)-0091-1-EF. Rockville, MD: Agency for Healthcare Research and Quality. October 2009.

[48] 6. McDonnell C, Werner K., Wendell, L. Electronic Health Record Usability: Vendor Practices and Perspectives. AHRQ Publication No. 09(10)-0091-3-EF. Rockville, MD: Agency for Healthcare Research and Quality. May 2010.

[49] 11. McDonnell C, Werner K., Wendell, L. Electronic Health Record Usability: Vendor Practices and Perspectives. AHRQ Publication No. 09(10)-0091-3-EF. Rockville, MD: Agency for Healthcare Research and Quality. May 2010.

[50] 7. Linder, J. A., Schnipper, J. L., Tsurikova, R., Melnikas, A. J., Volk, L. A., & Middleton, B. (2006). Barriers to electronic health record use during patient visits. *AMIA 2006 Symposium Proceedings*, 499-503. Retrieved November 17, 2008, from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1839290

[51] 8. Connolly, C. (2005, March 21). Cedars-Sinai Doctors Cling to Pen and Paper. *Washington Post*. Retrieved November 24, 2008, from http://www.washingtonpost.com/wp-dyn/a rticles/A52384- 2005Mar20.html

[52] 9. Ornstein, C. (2003, January 22). Hospital heeds doctors, suspends use of software. *Los Angeles Times*. Retrieved November 24, 2008, from http://articles.latimes.com/2003/jan/2 2/local/me-cedars22

[53] 10. Associated Press (2009, January 15). Lawmaker to investigate software glitches at VA. Retrieved from http://www.google.com/hostednews/ap/article/ALeqM5hzWcaC_f76P1tpPibAn0aRA83TLQD95NMFM02

[54] 12. Patrick J and Ieraci, S. Good HIT and bad HIT, MJA, 2013.

[55] 1. Robert M. Schumacher, Emily S. Patterson, Robert North, Jiajie Zhang, Svetlana Z. Lowry, Matthew T. Quinn, Mala Ramaiah. Technical Evaluation, Testing and Validation of the Usability of Electronic Health Records. Draft NISTIR 7804, September 2011.

approach. The variations we have made in our methods are described in a later section.

4.8 CIS Architecture

Whilst usability is commonly thought of as a matter of user interfaces there are other factors that affect the nature of the interfaces. In particular the underlying architecture has an influence on the manner in which usability is best served. The Substitutable Medical Applications Reusable Technologies (SMART) project has endeavoured to change the nature of serving usability by building a model of service delivery around web service APIs [Mandl et al (2012)]56. The objective is to achieve standardisation of system services rather than system design so the system builders are asked to develop standard APIs to access data from which external Apps can call for data and then provide some interface for the user that is independent of the underlying storage management system. The idea is that by making data accessible there will be sufficient encouragement to developers to expand the usability of the data for specialised applications. This is an experimental project that has been focused on initially demonstrating the basic architectural principles can be containers for established EMR systems and some charter applications to demonstrate functionality. The authors believe that the SMART standards as web based applications represent a major step towards a universal exchange language thus resolving the current blockage to interoperability of medical data. They also promote the view that a SMART architecture will create a wellspring of developers creating Apps that will form a dynamic market where the best will survive through a competitive advantage of superior usability.

4.9 Systems and Process Analysis

Analysis of the processes of information systems usage in EDs is an important part of developing designs that optimise staff efficiency and patient safety. A study by Weir et al [2007][57] showed that nearly half the identified processes required for order entry were not available in CPOE software. Complementary work by Pirnejad [2008][58] asserted that the main challenge on building an interoperable network needs to address its alignment with work processes.

Horsky et al [2010][59] studied the effects on ED staff processes of having to work

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[56] Kenneth D Mandl, Joshua C Mandel, Shawn N Murphy, Elmer Victor Bernstam, Rachel L Ramoni, David A Kreda, J Michael McCoy, Ben Adida, Isaac S Kohane. "The SMART Platform: Early Experience Enabling Substitutable Applications for Electronic Health Records." Journal of the American Medical Informatics Association (2012): n. pag. Web. 27 June 2012.

[57] Weir CR, Nebeker JJR, Hicken BL, Campo R, Drews F, LeBar B. A Cognitive Task Analysis of Information Management Strategies in a Computerized Provider Order Entry Environment. J
Am Med Inform Assoc. 2007 Jan;14(1):65-75.

[58] Pirnejad H, Bal R, Berg M. Building an interorganizational communication network and challenges for preserving interoperability. Int J Med Inf. 2008;77(12):818-27.

[59] Jan Horsky, , Matthew B. Allen, Allison R. Wilcox, Stephanie E. Pollard, Pamela Neri, Daniel J. Pallin, Jeffrey M. Rothschild.

across multiple patient information systems. They were particularly interested in how the complexity of cognitive tasks in this setting might effect medical errors and quality of care. Citing the literature they state that studies show team collaboration with system interaction, staff workload, clinical workflow, situational awareness, and the effects of technology on decision-making and cognition all need to assess when new systems are brought into service. The study was conducted across two ED sites and shadowed 21 staff of different of different physician and nursing roles over 4 weeks. There activity events at using different software and in different tasks were recorded. Duration of time at each event was not recorded. Five different electronic sources of patient data were in use: EDIS, EMR, LMR, PACS, WEB plus Phone, Paper and Dictaphone usage. Two sites were studied for the profile of activities of the staff. At Site A staff needed to switch between systems with separate logins and displays interfered with access across systems. In the second site the data from the non-EDIS systems were pushed into the EDIS so that staff had site of the patient record across the various sources at the one time. This led to different profiles of the usage of the multiple systems and greater satisfaction with the latter "more integrated" system.

A study by Intermountain Health (James and Savitz, [2011])[60] argues that following the principles of Deming that "improving quality reduces costs" investigated variation in clinical practice for a number of specific activities and worked at making the practices consistent across all physicians. That had the desired consequence of reducing costs without negatively effecting patient outcomes. They also describe a process of "shared baselines" where clinical guidelines are continually adapted under clinical experience which is also used to measure and control variation in clinical practice. This lead to a program to roll out these practices across the whole of Intermountain's operations over 160 hospitals. The process was called "clinical Integration and it had four components:

- identifying key processes;
- creating information systems designed for parallel clinical and financial management;
- revising the organization's structure so that it could use the resulting data to encourage accountability and change; and,
- aligning financial incentives so that clinicians would not suffer financial harm for doing what was best for patients.

Intermountain had assumed that it could use its administrative IT to achieve

Analysis of User Behavior in Accessing Electronic Medical Record Systems in Emergency Departments. AMIA 2010 Symposium Proceedings. pp311-315.

[60] Brent C. James and Lucy A. Savitz. How Intermountain Trimmed Health Care Costs Through Robust Quality Improvement Efforts. Health Affairs June 2011 30:6. Pp. 1-7. doi: 10.1377/hlthaff.2011.0358

clinical management, but this was discovered to be a mistake as it failed to monitor 30-50% of the required clinical data. In a decision to focus on measurement for improvement they adopted a formal methodology that identified a parsimonious set of variables for assessing clinical practice and subsequently built the information systems to support the capture of those variables for each of their key clinical processes. To 2011 they had implemented systems for 60 out of 104 key clinical processes having started with the largest activity areas of pregnancy and delivery and continued working down a priority list. In their assessment of their processes they state:

"we conclude that any organization basing its clinical measurements on inadequate internal administrative data and external regulatory requirements—rather than on intermediate and final clinical, cost, and service outcomes built around specific clinical care processes—will fail in its attempts to manage care delivery."

In reviewing the whole of their methodology and the reasons for its success they assert:
"Taken together, these policy changes are crucial. Truly "managed care" means "organized care"—care whose hallmarks include rich clinical and financial data that inform the decisions of clinical teams at the bedside; and clinical teams that employ patient-centered care processes leading to improved population health. Researchers must partner with practitioners to evaluate and demonstrate innovative financial alignment models. A central challenge for policy makers now is to align financial incentives and drive the transition to organized care systems that can provide "the best clinical result at the lowest necessary cost."

4.10 Outcomes Studies

The study by Rusteccia et al [2012][61] conducted a survey of quality managers and frontline physician to assess the correspondence between HIT uptake and quality measures. They showed that a higher level of HIT implementation measure correlated with a statistically significant greater number of QI practices and strategies. They had significantly better performance on mortality rates, patient satisfaction measures, and assessments of patient care quality by hospital quality managers. There was weaker evidence of higher assessments of patient care quality by front-line clinicians. This study was not able to show causality between degree of HIT implementation and superior performance on 4 out of 6 quality measures and so leaves open the question of whether hospitals with a more aggressive approach to process improvement through HIT are not also improving their processes through other measures, or whether the introduction of HIT is a motivator for systemic process improvements. Studies on

[61] Joseph D Restuccia, Alan B Cohen, Jedediah N Horwitt, Michael Shwartz. Hospital implementation of health information technology and quality of care: are they related? BMC Medical Informatics and Decision Making 2012, 12:109 http://www.biomedcentral.com/1472-6947/12/109

how HIT might drive or alternatively support process improvement are needed. To advance this work systematically the Data Quality Model[62] of the National Quality Forum will be an important backbone to systematic studies for quality improvement.

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62 National Quality Forum. Quality Data Model, June 2012 Update.

5. A New Theory and Praxis for Clinical Information Systems

The NIST studies give significant attention to the role of user centred design (UCD) and how it assists the development work of the software engineering process. We wish to assert a variation in this idea that changes a number of aspects of the UCD. We term our approach Clinical Team Led Design (CTLD) and it differs from UCD in these ways:

1. The clinician team takes control of the design of process and drives a process analyst team to produce the prototype system.
2. The prototype system is generated automatically from a Content & Process Design tool which eliminates the need for specific programming for the CTLD.
3. User testing is done progressively by the CTLD team as they bring all their professional colleagues in to assess progressive development and iterate the solution.

This approach to systems design can only come about because of the technology we have developed to remove all program code development from between the design process of a particular clinical application and the implementation process. Instead the code development is orientated on a generic solution to all clinical systems implementations. An early conceptualisation of this process can be found in Patrick & Budd [2010][63]. The consequences of this approach are substantial for certain aspects of historical usability namely:

1. The whole development process is a usability determination.
2. The clinical team do not need to compromise design for coding constraints (for the most part).
3. The supporting process analysts who assist the CTLD team cannot be separated from all functions of the team.

Usability testing also is given a different focus in this model with most of it falling into the formative function. As design is driven by the "users" then there function is to continually test and revise. The determination of the efficiency of the design is embedded within their own design thinking so there is a decreased role for summative testing. It occurs when there is concern for the inefficiency of a design, which may lead to a request to the software engineers to introduce a new designer tool function, or just trigger a rethink by the designers.

The NIST emphasis on Effectiveness, Efficiency and Satisfaction are addressed

[63] Patrick, J. Budd, P. Ockham's Razor of Design. Proceedings of the 1st ACM International Health Informatics Symposium, Washington DC. Nov 2010. http://portal.acm.org/citation.cfm?id=1882998&CFID=116605072&CFTOKEN=43603995

by the ECIS approach in a number of ways. This approach in principle removes the assessment criteria of Effectiveness as the CTLD team decide their own functionality hence a design can only be assessed for effectiveness by comparison to another system or criteria created external to the CTLD team. Efficiency likewise is determined firstly by the intrinsic work in the task and if it is a complex task the extent to which the CTLD team can remodel it to be easier or faster to complete. Satisfaction is still an open issue in the CTLD approach because although it will be robust for functional completeness the wider user base will have different preferences for exactly how to render screen processes, as we found in our interviews with clinical staff.

The notion of a CIS is commonly expressed in terms similar to what has been done in the last 50 years of systems development, resulting generally in unsatisfactory CERP systems. This has been because:

1. Most methods for defining information systems have been defined for business reasons across the whole business and are therefore generic business systems;
2. Systems analysts do not have deep insightful analysis of the clinical processes – e.g. my students sit there and say what do you want on the screen - I hear the word "alert" and realise that there are different types of alerts in different places. Alerts at triage are about known aggressive patients. Alerts at medications are about drug interactions. Alerts for allergies are about drug incompatibilities, but the students just generalise "alerts".

In an alternative world physicians have been building their own systems which are idiosyncratic and so they have suffered from:

1. a lack of skill to stay up-to-date with the improvement in software engineering methods;
2. Belief that one expert can speak for most and so adoption of a system closest to their own current work processes;
3. Not allowing for evolution of workflow and process methods;
4. Not allowing for local processes.

Hence the historical practice of systems development of waterfall designs and even more modern methods of agile design cannot meet the practical requirements of CIS design, that is there is a need to determine the nature of the methods of the workplace of each local community of practice, that is the local processes. The increasing use of user-centred design may go some way towards to supporting local processes and evolution but it still retains the design imperative in the hands of the systems analysts and software engineers.

The nature of the CIS should be to initiate new processes that enhance the productivity of staff particularly as a control and a management system that aids staff in doing the correct processes and disables them from doing incorrect processes that either lead to patient harm or their own inefficiency. At times

there is a balance between efficiency and safety so that processes have to run slightly less efficiently to get a greater gain in patient or staff safety. A new paradigm for CIS development needs to enable the creation of designs that are:

1. Optimum for workflows in the local community of practice, supporting the criteria that:

a) Brings together information that is needed at the one point in time for decision making - this means having everything on the screen you need (and nothing that will distract you)
b) Leads the user through a series of required steps;
c) Prohibits the recording of data that is not wanted;
d) Prohibits the recording of invalid data.

2. Enables the creation of improved workflows particularly for constraints by introducing:

a) new constraints for collecting data.
b) a different sequence for data collection.
c) alerts at different points in the workflow.
d) Assemblage of data in new ways for the decision making.

Hence as an alternative to older views of systems design and development methodology we combine all the features described in this analysis into a new methodology. We propose that an extension to the approach of user centred design where the clinical user has complete control of the design is the only method that will truly satisfy the use case of clinical information systems.

The praxis of this methodology then requires a software solution that delivers a clinical systems software design tool that is readily usable by the clinician designer team. Further, the design tool has to create a design that is instantiated by a processing infrastructure that performs all the processing functions defined in the design tool. There are three operational topics that need to be enunciated to fully progress this approach. These are to define the methods for: defining the ECIS architecture, defining the method of software engineering to create the design tool and design compilation; and, creating the CIS design.

The *ECIS architecture* is defined on the principle of *Ockham's Razor of Design*, that is, the elements of design that are engineered for the designer are the minimum number of design objects with maximal generalisation.
The *software engineering approach* is *Agile Programming* where the objects for creating designs are provided as the users create new imaginings of how they want their CIS to operate and the generalisation of the idea is fully enunciated.
The *CIS design* is created by a principle of *Agile Design* where designs are created and tested incrementally within an iterative process.

6. Emergent Clinical Information Systems (ECIS) and the Clinical Team Led Design (CTLD)

There are a great many of topics relevant to the task of building better CISs, but the words of Karsh et al [2010] are perhaps the most salient. The key task to improving HIT is close collaboration between clinicians and technologists who build these systems. In the remainder of this paper we describe a methodology that adopts the position of user-design of the required CIS. Furthermore we present a software solution that enables the user to take control of the design in a highly tangible manner. However while the users control the design they are supported by clinical process analysts who bring to bear their knowledge of optimal designs that is missing from the clinician's experience. The result is a coming together of expertises that requires negotiation but ultimately leads to a superior solution.

NEDIMS has been built on a technology we denote as Emergent Clinical Information Systems (ECIS) for which Clinical Team Led Design (CTLD) is an important principle. The technical details of the software engineering functionality will be presented elsewhere but the essential features of ECIS are:

1. A clinical team can design their own clinical information system using a specially developed Content & Process design tool;
2. The outputs of the design tool are automatically compiled into a run-time system that is used through a web browser;
3. Multiple CISs can be designed by independent clinical teams to run on the one application; and
4. Native interoperability enables data to moved from one CIS to multiple other systems as an automatic process without any need for messaging, thus enabling clinical teams to share data at their discretion.

The consequences of this architecture are that:

1. A system can be changed at anytime in near real-time;
2. No programming is required to convert designs and design changes into a run-time system.
3. A CIS develops incrementally with commissioning of components as the team sees fit.

The ECIS methodology enables the development of a CIS without the need to predefine the solution that is to be provided as in found in the classical Systems Development Lifecycle (SDLC) process. Designs can emerge over periods of experimentation with various competing designs. By creating the design in a creative environment the final design is emergent, that is, it has properties that are outcomes of the design process and not predetermined by the determinism of a software engineering methodology. Commissioning of certain subsections of large-scale solutions can be implemented so as to enable staff to acclimatise

to new processes gradually. Incremental installation also gives time to think about the appropriate sequence of introducing different components and learning from the installation process so as to improve it progressively. In this approach the design is never considered to be complete but rather something that will be changed as improved work processes are devised or new professional standards requires work practices to be revised. The ECIS methodology ensures that the process of creating the CIS is immediately available and inexpensive.

Placing the process of design in the hands of the clinical team can be justified in many ways but the net effect is to move responsibility for the working characteristics of the final designed system from the hands of systems analysts and software engineers to the clinical team. The following list of benefits is not exhaustive but highlight the most important:

1. Defining the role based clinical workflows.
   Any clinical department consists of staff with different roles and each with multiple workflows. In CTLD, as the design process progresses, the team can present the full clinical workflows of all roles in the team.
2. One Selective Implementation.
   The installation of an EMR usually creates a finite point in time where processes dependent on the EMR cannot be changed without significant battling with the vendor, let alone expense. Alternatively, a CIS is not a finitely defined system that is fully defined by a single requirements implementation. Rather, a CIS at one point in time represents the extent to which a collection of workflows has been defined by agreement between the staff.
3. Control of system expansion and evolution.
   In keeping with the principle that a system does not have to be fully defined, as is usually required by vendors, the ECIS will always need further extensions and modifications to be added at a later date. In CTLD, the team can ensure that the essentials are included to begin with and then they can manage the progression of system expansion and evolution in the CIS according to staff criteria and budget availability.
4. Expert knowledge of Operational Requirements.
   The expert knowledge of how a clinical department operates is held in the experience of the members of the department. These members are aware of the deficiencies of the current system and can enable the streamlining of work processes. In CTLD, they know much but not all of what needs to be changed to improve the system.
5. They know what they do not want when they see it.
   It is a classical requirements gathering problem of getting users to identify their requirements. It is most often the case in the clinical setting that staff have a poor understanding of what innovations would be useful to introduce. However, they are very quick to identify designs that are unsatisfactory for their work processes. Hence, in CTLD, clinical staff are

crucial to creating the right design, but also the ability to experiment with designs is equally important.

6. Clinical colleagues are best at convincing doubting colleagues to change work practices.
   In a large clinical department, there is a range of personalities with various values towards risk taking in changing processes. In CTLD, the clinical design team are best positioned to bring colleagues along with any innovations where there are any reservations and create the lowest barriers to acceptance of any innovations.
7. Immediate increase in productivity.
   The adoption of a CIS that meets with the acceptance of the staff across a large team will be seen as a positive advancement and immediately produce increased productivity from staff as they seek to validate its behaviour.
8. Professional training of new staff.
   The design of a CIS is often thought of as a repository of clinical content. This belies its role in dictating and regulating the manner in which work can be done. New staff, on joining a team, have to be inducted into the work processes of the team and the CIS is one of the early points in which staff are taught the local work processes. In CTLD, an optimal system design embodies the work processes required for the professional training of new staff.
9. Minimal training costs.
   In designing a system that is optimised for current team workflows, there is very little training needed for current staff, except for where the new system deviates from the old system. In CTLD, a design that follows the logical processes of the department will keep training costs to a minimum as most of the staff will know most of the processes in the designed system.
10. Minimal re-training costs.
    Traditionally out-sourced CISs carry a significant overhead for staff to be trained on how to use them. Subsequently, staff take time away from the department and return needing to be retrained in parts of the system. In CTLD, clinician-designed systems match the department workflow, so continuous training and refresher training costs are negligible, because the CIS is known and understood as an intrinsic part of each staff role's work processes.
11. No dependency on a super-user.
    In CTLD, there is no significant dependency on a super-user to resolve difficult processing, so there is no time wasted searching for the "right" person with the right knowledge on how to use the system.
12. Workarounds are minimised.
    Workarounds are typically the product of poorly designed EMRs that need to be circumvented, either because of dangers to patients or inefficient work practices. In CTLD, workarounds are minimised as they are either a

validated process in the workflow or the system is changed to incorporate their purpose.

13. Minimised duplication of data entry.
    In CTLD, duplication of essential data entry is minimised as data is captured at the appropriate point of collection and then distributed according to mechanisms provided by the CIS.
14. Identification and adherence to appropriate standards.
    In CTLD, the team are able to identify the points in the workflow process where adherence to standards is required so as to ensure data can be compared for the purposes of research and audit.
15. Harmonisation of departmental skills.
    A large clinical department has staff in many roles with many skills. This gives rise to alternative and competing views of the best processes to use in a given setting. In CTLD, the clinical team can harmonise and utilise the group's range of clinical and technical expertise and skills in the design process to ensure an optimum solution.
16. Capture process of patient care.
    Historically, the design of EMR has been to solely preserve data considered relevant to the practice of medicine. Alternatively, the clinical team has an intimate understanding of the journey the patient has to make through their clinical processes. In CTLD, the team can more accurately reflect the process of patient care.
17. Increase staff awareness of their own processes.
    In CTLD, the team can enable streamlining of work processes as they engage more heavily in the analysis of their current processes and so become more aware of how they can improve them.

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7. Project Aims

The aim of this project was to investigate the possibility of producing an "ideal" information management system for one emergency medicine department. This task requires a process of determining the information systems needs of the emergency staff, designing an ideal system and then attempting to reproduce the ideal system as an operational system. The project required significant interaction between the IT and clinical staff to achieve a clear and accurate specification in the first instance and then for the appraisal of the developed technology. The project had the following objectives:

1. Assess the capacity of staff to design their own CIS;
2. Assess the capacity of the ECIS technology used for the design process to satisfy all the demands of the design team;
3. Assess the differences between the NEDIMS and the CERP for:
    a. Efficiency of operation;
    b. Cognitive load;
4. Assess the effect of the clinicians' design on:
    a. Workarounds;
    b. Paper processes;
5. Assess the trainability of NEDIMS;
6. Build a model of patient journeys and assess it for differences between NEDIMS and the CERP for that model;
7. Identify the processes of interruptions and consider methods for minimising them.
8. Make a qualitative assessment of the differences between the two systems for patient safety, staff productivity and clinical audit;
9. Assess the costs and ease of modifying the system and provide an evaluation of the ROI in making those changes.

7.1 Process

The task revolved around several processes:

1. Systems Analysis: An IT team collected a set of descriptions of the tasks and workflow performed by Emergency staff in sufficient detail to believe that a clinical information system dealing with the information collected would increase their productivity, and

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2. Systems Design: the design of an information management system by the clinical staff supported by the IT staff that served the needs defined in the Analysis and defined the "ideal system".

3. System Construction: IT delivered such a system that staff would use and establish to be a productivity advantage, building and testing progressed iteratively with changes made incrementally during the construction process, and,
4. System Testing: Once the system conformed with a design that clinical staff believed would provide them with acceptable productivity gains the system was tested in the department to evaluate its actual performance standard.

5. System Performance - User Acceptance. The usability standards of the system was established in the trial conducted by the staff, and by comparison with the "ideal system" defined by staff in the analysis stage.

The collection of descriptions required the IT staff to have access to the working environment of the department and to trace the collection of information and its flow throughout the department. ED staff needed to fully inform the IT staff of all their work processes. This was often difficult because many processes are actuated only rarely and it was difficult for staff to remember them if they had not been performed recently. IT staff needed to collect all forms and screens of information used by staff and understand how those forms/screens support the workflow of the group. Ultimately the IT staff drew up diagrams and wrote descriptions of the information collected, its source and the various destinations at which it was used.

Once the systems analysis was completed to a satisfactory level of detail, then meetings with staff were conducted to design the "ideal" system. This required meetings between the two teams to establish a hierarchy of priorities for implementation.

The design led directly to the construction process where the iCIMS technology was used to create working components of the system and ensure that the workflow in the system was consistent for the clinical staff. Incremental testing with clinical staff was conducted throughout this process.

System testing occurred initially in simulation scenarios. The aim was to tune the data capture and display processes and the workflow support. Modifications were installed during this process. The two performance criteria were also assessed at this time.

8. Research Methodology

It is not evident that there is a clearly defined research methodology for the task of comparing the working operations of two CIS. However, there are a number of conditions that need to be specified in a comparative investigation of this type, namely that:

- The hypothetical system be specified and designed by the local clinical team who will use the system.
- The designed CIS is fit for purpose.
- The test tasks will be in vivo work performed in an actual clinical setting.
- The two systems will be tested on their efficiency at doing the same tasks.
- The objective measures of performance are to be the time to do a given number of tasks and the number of mouse clicks required.
- The set of tasks and frequency of observation needs to be determined.

This has to be a contrastive study of system A vs B. The hypothesis is that one system serves the needs better than the other with the following needs being defined as the most important:

1. The correct data is captured;
2. The constraints on data capture are enforced;
3. The workflow process for capturing data is enabled;
4. The appropriate data is available When & Where it is needed for reuse/decision making;
5. Data is presented in the clinically most desirable manner;
6. Data can be exported;
7. Data can be imported;
8. Compilations of the data can be reported;
9. Ad hoc questions can be answered;

Operationalising these criteria produces a number of issues that need resolution.

Enabling the clinical staff to design their own system requires a technology and the time and effort to commit to the task. The IT system adopted for this task was at hand for the beginning of the project (Patrick& Budd, op cit). This technology has the particular characteristic that enables the design of a clinical information system through a GUI and from the design an automatic process for compiling the working CIS. This software ensured that the clinical team could work on the design and no subsequent intermediate programming was needed to create the working system. The net effect is that the design changes are implemented in near real-time.

Performing the tests by timing in vivo work although desirable is not entirely possible. The compromise is created by the real work needing to be done on the hospitals installed system if the cases were to be live cases demonstrating actual work practices. Having done the work tasks live on the hospital CERP system it

was not possible to do the same "live" on the local CIS. The strategy adopted was to follow the clinical staff in their daily work and measure their in vivo work on the CERP system for time to do a task and count the number of clicks required. Subsequently the researcher (AB) replicated the same task on NEDIMS inputting the same data. Where necessary photocopies of the text or paper documents were provided to ensure the record contents were complete and matched the original data record. The only difference in the records was that the patient details were anonymised.

The outcome of the work was that each task was performed as a part of actual patient care on the CERP system with time duration and mouse clicks measured, subsequently the same task was repeated on NEDIMS with the time duration and mouse clicks measured giving a set of comparable results.

The project proceeded in the following manner:

1. Ethics approval was sought and granted for a time and motion study of the Nepean ED[64].
2. A clinical team developed the initial design in an iterative feedback process.
3. The design was bench tested by 20 staff and further changes completed.
4. A process analysis of the department was completed in detail for documentation, further revisions to NEDIMS, and identification of all tasks to use in the testing.
5. The staff were followed over a period of time until it was considered sufficient data was collected.
6. The recorded staff tasks were repeated in NEDIMS by the researcher, with time and motion tracked.
7. The task descriptions and early stage results written up and reviewed resulting in a proposal to redesign and retest parts of NEDIMS.
8. Redesign and retesting was completed.
9. The final report was completed.

[64] Ethics Approval granted by the Nepean/Blue Mountains Human Research Ethics Committee

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9. Design Methodology used to create NEDIMS

Any functional clinical environment has a system currently in use, whether it be solely paper or partially electronic, with a large amount of content and workflow that is working satisfactorily and can be used as the base model for a new CIS. The aim for the new CIS is to install as many functions as electronic processes as needed that will make it able to satisfy current aspirations.

The notion that a CIS is designed in its entirety at one point in time usually proves to be a very brittle model. The ECIS methodology used in this study holds that the best solutions emerge over time with incremental development continually advancing from one level of functionality and complexity to the next with the experience of what has been achieved to date.

Where an electronic system is already in place and needs replacement because it is becoming moribund and decaying in usage or staff are seeking radically improved usability, then a great deal of knowledge about the computerisation of clinical processes resides in the workforce. This knowledge is highly valuable as a springboard to designing the next generation system.

The technology developed and used to design NEDIMS in this research caters for the above theory of CIS design methodology. A Content & Process (C&P) designer tool was developed and used to design and execute any CIS, in this case, NEDIMS. The C&P tool is a software package installed on the designers' computers that allows them access to a designer's interface with a list of systems and forms to create and modify. A user can simply create and link forms through a user-friendly interface by drag and drop mechanisms and property boxes for design objects. A set of about 20 widgets is available to add and configure any form as required. The widgets theoretically encapsulate all required functions to design a completely operational form. On saving a design it is compiled automatically so as to generate the working system as a web application without the need to write any program code.

The use of the C&P tool as part of the methodology allows for agile CIS development eliminating the need for engineering or coding to design and execute a specific CIS. It also empowers clinical design teams to take full control of the design development with hands on, using the technology tools without prerequisite knowledge of IT coding languages. In addition, modifications to any form as part of the requirements stage as well as an operational stage are completed in near-real time.

9.1 NEDIMS Design Development Stages

The ECIS methodology adopted in this study followed these stages as an iterative and integrated process of requirements gathering, and design:

1. Collection and replication of the current system's data recording methods whether it be in paper or electronic forms;

2. Iteratively review, collect more content and integrate into the current design;
3. Collect a description of the data flow to capture the movement of data from one form to another;
4. Collect a workflow description to capture the user movement from form to form;
5. Use Case Development and functional testing, where the design of the system is validated against the expected work processes defined by the design team and then tested by staff using retrospective data (See Appendix 1: NEDIMS Use Cases for Bench Testing);
6. Evaluation of testing outcomes by the clinical design team to decide and integrate design revisions and/or additions;

Two extra steps would normally be used when a system is required for full commissioning but were not done in this case:

1. Use case testing for concurrent usage to assess the system's impact in its working environment as well as a second evaluation of CIS design post-revision;
2. Semantic definition by universal coding to capture the semantics of each component of the represented data.

Generally, the following requirements will need to be defined for the design and delivery of the CIS:

- The functions in the current system and the direct modifications that are required;
- The new functions or extensions required.

The modifications and extensions to existing functions were developed in weekly team meetings with the clinical design team. Staff members from particular specialised areas were also co-opted on a regular basis. The processes of design development are cyclic and iterative as the new designs emerge, are tested, and reformulated to better support and improve the staff's workflow and patient safety.

The work was completed over a period of 18 months with periods of intense work and quiescence at other times. During active times the design team met with the clinical team between once a fortnight to once a month. It is estimated, retrospectively, that the designer (AB) spent about 650 hours on setting up the design, discussions with staff and bench testing the design. The team meetings for 4 people required about 100 hours (25 hours each). The workflow analysis was performed over 3 weeks requiring about 40 hours of staff time and then followed the comparative testing for the two systems which required about 350

staff hours by two staff over five weeks.

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10. Overview of NEDIMS Design

This section presents an overview of the general design strategies employed by the clinical design team in designing NEDIMS. The basis of the CIS design lies in defining the system's main/home generic screens (mainly patient lists), the patient record with all its associated forms, and the interaction between both. Next is the actual forms and lists required in the system, including current screens to replicate or modify, new screens/forms (such as extra lists or specific functions that do not currently exist), and paper forms. The actual dataflow and workflow and how all the "bits and pieces" from the previous 2 stages of the design phase are exploited further is a highly iterative process that combines all aspects in a coherent CIS design.

10.1 Front Page (Home Screen) and Associated Tracking Lists

Figure 1 presents NEDIMS' main/home screen. The default view is for all patients currently in the department split into three categories: Waiting to be seen, Seen, and Admitted. Each table displays a series of auto-populated fields defined by the clinical team based on the most readily required fields for retrieval as per each of the three patient categories. For instance, admitted patients table includes an "Admitting Medical Officer – AMO –" column which is not relevant for the first 2 tables but only for the 3rd table. The tabs listed across the top of the screen allows exclusive viewing of each category separately, or to view patients by their specific location in the department. Within each patient row in the table, there are buttons labelled "Pt. Chart" to directly access the patient record.

10.2 Patient Record and Associated Forms/Screens

The clinical design team opted for a patient record screen to browse all parts of a patient record under a structured main menu screen defined as the "Patient Main Screen". This screen can be accessed for any patient from the home screen by clicking "Pt. Chart" enabling access to any patient record item for data entry, modification, or retrieval (Figure 2). The screen is designed with static and dynamic panels. The top 2 panels with the patient menu items and patient demographics/basic information are static to increase useability in accessing different parts of the patient record, while the 3rd panel dynamically changes as the user selects which form of the patient record they have selected. The main patient menu items include:

- Clerical
- Triage
- Vital Signs
- Patient Care Summary
- Clinical Documentation

  - Clinical Notes
  - Order Pathology/Radiology
  - Diagnosis & Clinical Pathways
  - Discharge Summary
  - Handover Plan
  - Sickness Certificate
  - Prescription Pad
  - CIN Form
  - IV Order Form
- Nurse Tasks
- Disposition

Overall, every form of the patient record is designed for maximum optimisation opportunities including:

- Conditional displays to reduce cognitive load on the user. The user needs to see only the relevant parts of a screen based on their selections. For instance, if no trauma injury is selected, no option to enter trauma details is displayed. This is designed as an automated data validation mechanism rather than retrospective system warnings or alerts about inconsistent data which can be distracting to users.
- Automation of data transfer between patient forms to reduce double data entry. Where data is collected on one screen and reused on another screen it is automatically transferred.
- Design fit-for-screen forms according to the organisation's standard screen sizes to reduce scrolling.
- Reduce unnecessary 'white space' on forms to increase visual coherence of the forms while maintaining logical separations of different sub-sections.
- Splitting of longer forms into multiple screens to fit with workflows specifically where multiple roles contribute to the same processing screen.
- Addition or modification of forms to add/remove fields and functionalities down the track in real-time as required.

10.3 Paper Forms

Integration of selected paper forms into NEDIMS was completed as part of the

scope of the study. The addition of a new form does not affect current processing or data handling in the CIS. The first objective was to design the forms to identically match the paper equivalent visually. The second objective was to automate the form where applicable, such as pre-populating data into the form that would be already entered elsewhere in the system to reduce double-data entry and handling. Figure 3 shows an example of a paper form (Prescription Form) integrated into NEDIMS. Other included paper forms are CIN and Sickness Certificate forms.

The forms are integrated where they are relevant in the workflow. The addition of new paper forms can be a staged process as it does not affect the current system's workflow and data handling. In fact, the technology allows for integration of the forms into the workflow and data storage with minimal to no risk on current operations.

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11. Data Collection Processes

11.1 ERP Data Collection

Data collection in all 6 locations (Clerking, Triage, CIN, Fast Track, Acute Care, and NUM) was completed in 22 days. In each location, the researchers were stationed at the terminal hubs consisting of 2-3 terminals (except for Triage and NUM which consist of a single-terminal each). Staff were briefed at the start of each data collection session by the research supervisor and assistant to gain their consent and assure them that data collection would not interfere with their normal work in any way. All staff members approached throughout the study consented.

A template for recording the data was developed (see Appendix 2). Timers and data collection sheets were used in capturing terminal-side tasks. The researcher was in charge of timers and click counts while the research assistant captured and recorded information on the data collection sheets. The timer was started as soon as the user sat at the terminal. Time was then lapped every time they finished a task and started a new task, or were interrupted. The timer was then stopped as the user left the terminal. Throughout the timed session, the researcher assistant recorded all task information as defined by the template.

The assistant would also record the patient name on a separate sheet and assign it a unique de-identified code that was recorded on the data collection sheet. This was required to retrieve the correct patient records and repeat the same tasks with exactly the same data recorded. The code-to-patient mapping sheet was stored securely at the hospital ED admin offices at all times so that no patient identifying information left the hospital.

11.2 NEDIMS Data Entry/Collection

A template was developed to record details of tasks entered into NEDIMS as a replication of the tasks carried out on the CERP system (see appendix 2). The de-identified patient code was recorded in the template and mapped to a randomly generated unique NEDIMS identifier for hypothetical patients created in NEDIMS for the purpose of the study. Access to CERP system and paper medical records was granted to retrieve patient records for de-identified data entry into NEDIMS. The researcher recorded time and clicks as the research assistant executed the tasks on NEDIMS and recorded the information on the NEDIMS data collection sheets.

12. Workflow Analysis

See Volume 2

13. Results & Analysis

See Volume 3

14. Evaluation of ECIS & NEDIMS against the Literature

There are five papers that advocate various aspects of CIS design. ECIS fulfils the vision of the AHRQ by fulfilling the criteria of being "responsive, expansive, flexible and resilient". It is also maximised to "run smoothly, efficiently and safely".

ECIS goes some distance to fulfilling the requirements for improved usability asked by human factors researchers (Beauscart-Zephir et al, Staggers et al (op cit) by supporting control of the design by the clinical team. In the ECIS method the clinical team is supported by clinical process analysts who bring a great deal of system design experience to complement the clinical team's knowledge of their own processes. By handing control of usability assessment to the clinical users there is a great deal of ad hoc usability testing in the experimental phase of the design.

Farley et al [2013] produced a list of 7 recommendations, 4 for end-user behaviour and 3 for vendor behaviour. The ECIS method supports all of these recommendations implicitly because response to discovery of problematic practices can be made extremely quickly hence reinforcing the proposed behaviours. By being able to make changes rapidly staff will become engaged in all the practices they recommend because they will have a belief that they can make a difference. The authors also emphasise the importance of designing to satisfy "task- and user-specific properties of work" which is readily achieved in the ECIS method.

Octo Barnet produced a set of Ten Commandments most of which ECIS conforms to:

	Octo Barnett Commandment	ECIS Conformity
1.	Thou shall know what you want to do	The method requires clinicians to specify their requirements.
2.	Thou shall construct modular systems - given chaotic nature of hospitals	ECIS supports unique systems for each specialty on the client side.
3.	Thou shall build a computer system that	ECIS allows modification and extension as required by the

	can evolve in a graceful fashion	clinical community.
4.	Thou shall build a system that allows easy and rapid programming development and modification.	ECIS allows real-time modification.
5.	Thou shall build a system that has consistently rapid response time and is easy for the non-computernik to use.	ECIS systems are designed by the users who know what is going to work the best for their community.
6.	Thou shall have duplicate hardware systems	A matter for the hospital IT department.
7.	Thou shall build and implement your system in a joint effort with real users in a real situation with real problems.	Clinical team led design ensures user control of the design. Building the CIS is automatic.
8.	Thou shall be concerned with realities of the cost and projected benefit of the computer system.	The clinical community can determine their effort and the return it provides them.
9.	Innovation in computer technology is not enough; there must be a commitment to the potentials of radical change in other aspects of healthcare delivery, particularly those having to do with organization and manpower utilization.	ECIS support for continuous process improvement introduces the organisational issues.
10.	Be optimistic about the future, supportive of good work that is being done, passionate in your commitment, but always guided by a fundamental skepticism.	Yes, we agree.

Karsh et al [2010] set out 10 fallacies about HIT and how they cause a disservice to achieving better performance of HIT. ECIS does not suffer from any of the fallacies listed by the authors. Each individual fallacy is addressed in the table below.

	HIT Fallacy	ECIS Alternative
1.	”risk free”	ECIS lowers the level of risk do to incremental development allowing controlled management of development and releases at short or long intervals with capacity to rapidly correct faults at low costs.

2.	"HIT is not a medical device"	ECIS allows greater scrutiny and validation of any application as testing is controlled by the client not the vendor.
3.	"the clinician as learned intermediary"	The clinician has responsibility for the design and the technologist is responsible for the software performing correctly, thus the two groups divide responsibilities more clearly.
4.	"use equals success"	This is circumvented as the CLTD team dictate when use will commence and that can be restrained until the design has been tested sufficiently to guarantee acceptance by the whole team.
5.	"messy desk characterture"	This is negated by the CTLD creating a configuration that allows the mosaic work patterns of staff to flourish and at the same introduce appropriate professional standards of work that staff should conform to.
6.	"father knows best "	As the clinical team manages the design process they can produce a solution that meets their needs and any secondary user of their data has full access due to the underlying enterprise architecture.
7.	"Field of Dreams"	The designer and the clinical team are the same people hence there can be no transference of blame from one party to the other.
8.	"one size fits all"	The freedom of design ensures that each party of interest can be provided their own design except at points of direct conflict of process when the parties have to negotiate an agreed solution.
9.	"paperless office" principle	ECIS systems are initially built on a model of paper forms which are gradually transformed into more dynamic workflow as the clinical team build more sophisticated solutions. Any ECIS can efficiently operate in collaboration with manual processes until they are computerised.
10.	"no-one else understands healthcare"	This does not arise as the clinical team control the design process entirely.

These authors promote the view that systems will improve with more engagement with the clinical users although they are still wedded to the SDLC model where all requirements need to be carefully defined in advance. Many of their criteria for design success are captured by an ECIS approach, namely, "clinician and patient ease of learning, time to find information, time to solve relevant clinical problems, use errors, accuracy of found information, changes in task and information flow, workload, situation awareness, communication and coordination effectiveness, and patient and clinician satisfaction".

Before and After Assessments give the opportunity to understand methodologies for conducting this type of comparative investigation. A report by Baumlin was shown to indicate benefits from the introduction of an EDIS in terms of reduction in stay and other performance KPIs across the ED. We have not been able to

address these wider indices in this study but the implication is created by these results that KPI values will improve as the scale of the efficiency gains shown in this study are so large, at better than 40%.

Asro and Banet showed that the time spent on computer terminals increased as time on paper decreased whereas our study shows from the CIN results that the time spent on mixed computer+paper tasks decreased significantly by 45.9%. An extension of this study by Banet et al [2006] showed that nurses perceived they were using less time for documentation whilst objective measures showed no change. They concluded that nurses' computer experience could be effecting their results. In the NEDIMS study it is clear that processes are intrinsically faster but there is no test with actual staff to understand the variations that might arise due to differential expertise. The listed benefit for CTLD that staff will use the system more readily because it closely matches their existing workflow argues for a sustained improved efficiency across all staff.

Bisantz et al [2010] and Wears & Perry [2007] and Wears et al [2003] all identified various content around patient status boards that might be lost with electronic systems. Although not explicitly tested in this study there is some indication that this is less of a risk with the ECIS solution. We have described the process of revising some tasks once they were shown to be more efficient in FN so as to improve their efficiency. We have also described the implementation of the FAQ screen containing the Management Plan which was created as a stopgap while a more systematic approach was established. These examples all indicate that when a function in the manual system is missing in the CIS that the ECIS methodology is robust enough to support fixing the weakness in very short turnaround times and with optimal efficiency and rapid recovery of the time expended in modifying the system.

Only a few In Vivo assessments have been identified. In a French hospital (Carton et al, 2002) staff were provided with advice on radiology orders. Trainees were the staff to most frequently deviate from the guidelines at 70%, and the report recommended the most important aspect of system design was to discover the processes of the individual department. As ECIS has CTLD as its basic principle it is consistent with this advice. A number of studies have shown that EDISs have contributed to both increases (Connelly et al, 2012, Mayer et al 2010) and decreases (Connelly et al, 2012) in length of stay. As no live tests have been performed with NEDIMS we cannot establish if the LOS is changed by its introduction. However there are clear indications that it will at lest not extend LOS even if it does not decrease. The results from the short duration locations in the Nepean ED clearly indicate that NEDIMS would save time and this could be expected to directly reduce the patient LOS. As Acute Care patients are complex it is less obvious the patient LOS would be changed nevertheless it is clear that it would not make it any worse.

Post Implementation Studies identify the consequences of the installation of an EDIS. The Park and Chen [2012] study reveals many interesting facets relevant

to the CTLD process. They identified the mutual ignorance of clinicians and usability designers in collaborating to arrive at an implementation. They also pinpointed the insufficiency of the EMR to service the special purpose needs of the ED which forced staff to create workarounds to maintain their efficiency or safety. They identified the richest learnings from the design process being created when the staff developed their workarounds. The ECIS approach directly addresses the need for workarounds and the capacity to eliminate them. In the NEDIMS setting there are many cases of workarounds that were removed from the staff processes. A notable workaround is the practice of the triage nurse creating a paper record that is used by the staff because of the perceived insufficiency of the electronic record.

The field of CPOE has an accumulated literature that is not relevant to this study but there are some general findings that are pertinent. Murf & Kanry [2001] came to the conclusion that design issues were critical to staff acceptance, after identifying that the in-house developed CPOE system at Veterans Affairs received higher efficiency rating than a commercial system. They also pointed out that this was a consistent finding throughout the 1990s. ECIS clearly represents the first system to allow the staff to take complete control of the design process. This does not mean that they should be left to their own devices as it is important that they be supported by process analysts who can contribute greater experience about what makes a good design. Rain et al's work [2012] implicitly supports the ECIS model where they showed that a Best-of-Breed solution had a lower error rate than an enterprise solution. Research by Asaro and Boxerman [2008] indicated that for a CPOE system doctors had their time with patients decreased and the process of introducing a CPOE needs to be considered in the light of wider medical practice. ECIS enables the clinical team to investigate the effects of their design decisions by trying different approaches that may be conditioned by very local or very widespread considerations.

A concept paper prepared by Sinsky et al [2013] advocates point of use modelling and testing. They use a flight simulator analogy to argue for reporting problems by a simple button on the user interface. With the ECIS it possible for the clinical design team to set up such a reporting system as needed.

Usability studies while extensive as a field are not frequent in the context of EDs. Survey studies by Bundschuh [2011] and Batley [2011] both identified high user satisfaction was directly credited to careful system design. Studies that identified facets of particular systems that needed usability improvements are Singh et al [2013] and Zhang et al [2009]. A NIST study by Schumacher & Lowry [2010] presented a review of the literature to make the point that usability is a key issue in creating good HIT.

The CTLD process is supported by Lapoint & Rivard's [2004] study that revealed engaging users early in the design process was invaluable but this also revealed power struggles between nurses and doctors that needed appropriate management.

The value of CTLD is supported by a number of studies (Weir et al [2007], Pirnejad [2008]) which have investigated the issue of completeness of design and identified shortfalls that inhibited efficient work process. CTLD in these cases could not identify missing processes but it could prioritise their importance in any phased introduction of their computerisation.

Horsky et al [2010] performed a study that is the closest in methodology to this study. They compared staff task usage across two different systems but did not record the time of engagement in each task. The difference between the two sites was that one had better support for switching across multiple CIS to get needed data. This not only created different profiles of usage, but also greater satisfaction with the more integrated system. This study indicates that an ECIS solution must not only deliver the services defined by the clinical team but also access data from other locations to bring it into the ECIS, hence necessitating an external messaging function.

Two studies indicate that quality improvement can be driven by improved HIT, namely Rusteccia et al (2012) and James and Savitz, 2011). These studies show evidence that engagement of staff in the process improvement leads to more productive outcomes. The ECIS approach is focused on achieving exactly this engagement and provides a direct method by which it can be achieved. Once the authority and the mechanism to design the CIS is placed in the hands of the clinical team then their engagement is guaranteed.

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15. Conclusions

See Volume 3

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Appendix 1: NEDIMS Use Cases for Bench Testing

Use Case Step/Function	Functional Test
From tracking, log on (top left corner of the screen)	Login Successful (Y/N)
Workflow 1 – Patient exists on tracking & needs clerical registration	
From tracking, identify a patient who needs a clinical registration completed (i.e. 'Cl reg' column checkbox is not ticked)	Identified? (Y/N)
Highlight a patient by clicking anywhere in the patient row	Highlights (Y/N)
Go to the Clerical form via "Pt Chart" button then click on "Clerical" tab item	Clerical Form Opens (Y/N)
In the clerical form, pre-registration details are displayed – tick full registration box and complete all patient details	Full Reg fields display (Y/N)
Click on "Order clinical notes" checkbox	
Record status of clinical notes	
Click on 'SAVE' and confirm save	Save successful (Y/N)
Return to Tracking - check that Full Reg box is ticked	Checkbox Ticked (Y/N)
Workflow 2 -creating a new pt episode	
From tracking, click on the Create New Patient Clerical button at the top of the screen	A Create New Patient details opens (Y/N)
Create a new patient (use any MRN and 3 patient identifiers e.g. DOB, name, sex)	
Click on Create Patient button to confirm new patient	Check on Tracking Patient has been added to 1st table (Y/N)
Workflow 3- finding patient information	
From tracking, pick a patient and locate the following:	
Presenting Problem/Diagnosis	Identified? (Y/N)
Triage category	Identified? (Y/N)
Clinical documentation	Identified? (Y/N)
Discharge letter	Identified? (Y/N)
Workflow 4 – Admitted patients	

From tracking, identify an admitted patient (on 3rd Tracking List)	Identified? (Y/N)
Admission paperwork is complete, record this on tracking (via patient chart/disposition screen)	Disposition form open (Y/N)
Save and go back to tracking	Admission Checkbox on tracking is checked (Y/N)

Table 1. ED Clerical Use Cases for NEDIMS

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Use Case Step/Function	Functional Test
From tracking, log on (top left corner of the screen)	Login Successful (Y/N)
Workflow 1 – Assigning yourself to a patient	
From tracking, highlight a patient in the "patients to be seen list". Click on the 'MO/nurse' button	Assign Provider form opens (Y/N)
Add your details, date and time to the form, then save and close	Save successful (Y/N)
On tracking, click refresh Tracking button. The patient should now appear in the 'seen' list	Px appears in seen list (Y/N)
From tracking, highlight the patient by clicking anywhere in the patient row	Highlights? (Y/N)
Go to the Patient Care Summary form (by clicking on "Pt Chart" button for the patient, then tab item "Patient Care Summary), triage benchmark timer should have stopped counting down when you assigned yourself	Px Care Summary Opens (Y/N). Timer has stopped (Y/N)
From here, go to the "Triage" form (via Triage tab item)	Triage form opens (Y/N)
Workflow 2 – Documentation	
From tracking, highlight a patient in "Seen Patients", document your assessment & findings (Via Pt Chart > Clinical Documentation > Add Clinical Note)	Clinical Note Added Successfully (Y/N)
Open a clinical pathway matching presentation under the "Clinical Documentation" tab	Clinical Pathway open successfully (Y/N)
Complete the Clinical Pathway form and save	Form saved successfully (Y/N)
Still under Clinical Documentation, insert a diagnosis in the allocated diagnosis field and save	Diagnosis saved successfully (Y/N)
From documentation, view vital signs (via pt vital signs button)	Vital Signs open successfully (Y/N)
Workflow 3 – Requesting nurse tasks	
From tracking, identify your patient and go to Nurse tasks form (via Pt Chart > Nurse Tasks) or double-click through on the Nurse Task field on tracking	Nurse Task form open (Y/N)

In the nurse task form, request a nurse task i.e. ECG, IVF. Complete request, sign, and date fields and save	Save successful (Y/N)
Go back to tracking , your request appears in the nurse task column of your patient	Request displays (Y/N)
Workflow 4 – Patient for admission	
A team/VMO has seen your patient and wants them admitted under them. Open the disposition form (Tracking > Find Patient > Pt. Chart > Disposition tab item)	Disposition Form opens (Y/N)
In the 'disposition' form record: Bed Request Date/Time/Your Name, Special Requirements, Select Discharge Process (Admit to Ward). Then Save Form	Save successful (Y/N)
Return to tracking. On tracking the patient has moved to the admitted section	Patient Appears in Admitted List (Y/N). AMO appears on list (Y/N)
To satisfy access block, your patient plan has to be handed over. To do this, go to the "All Patients" tab. Sort the table by MO.	Sort Successful (Y/N)
Highlight your first patient and 'go' to the handover plan	Handover Plan Opens (Y/N)
Record data, your name, date and time then Save	Save successful (Y/N)
Workflow 5 – Patient discharged from ED	
Complete discharge letter (via Pt Chart > Documentation > Discharge Letter). Save	Save successful (Y/N)
From documentation, navigate to the disposition form (via disposition button) record a patient disposition of 'treatment complete' in the 'departure disposition' field. Record date and time. Save.	Save successful (Y/N)
From tracking, departure status is visible to all staff.	Correct departure status displaying (Y/N)
Workflow 6 – Finding patient information	
From tracking, pick a patient and locate the following:	
Vital signs	Identified? (Y/N)
Presenting Problem	Identified? (Y/N)
Triage category	Identified? (Y/N)
Patient's NOK	Identified?

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	(Y/N)
Clinical documentation	Identified? (Y/N)
Discharge letter	Identified? (Y/N)

Table 2. ED Medical Officer (Doctors) Use Cases for NEDIMS

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Use Case Step/Function	Functional Test
From tracking, log on (top left corner of the screen)	Login Successful (Y/N)
Workflow 1 - patient exists on tracking	
From tracking, identify a patient who needs a triage (i.e. no triage/presenting problem is present)	Px Identified (Y/N)
Highlight the patient by clicking anywhere in the patient row	highlighted (Y/N)
Go to the patient's Triage form (Click on Pt Chart > Triage tab item)	Triage form opens (Y/N)
Select presenting problem of abdominal pain and click "Go"	Abdominal Pain Manchester form pops up (Y/N)
Choose a category 2 & 3 Manchester discriminator, then Save and Close	Save Successful (Y/N)
Complete triage form: Allergy, Trauma Status, Pulse, BP, Respiration, GCS. Check location is set to emergency and select a bed. Save and return to tracking.	Save Successful (Y/N). Triage category and presenting problem display on tracking (Y/N)
Workflow 2- create a new patient encounter	
From tracking, click on the "Create New Px (Triage)" button at the top of the screen	A Create New Patient details opens (Y/N)
Add patient details (use any MRN and 3 patient identifiers e.g. DOB, name, sex, etc...) Click Create Patient	Patient is created and Triage Form opens (Y/N)
In the triage form, add a presenting problem of 'chest pain' , click on 'go'	Chest Pain Manchester form opens (Y/N)
Choose a category 2 & 3 Manchester discriminator, save and close	Save Successful (Y/N)
Complete triage form including any vital signs then save and return to tracking	Save successful and patient appears on "To be Seen"

	list
Workflow 3- Treatment commenced	
From tracking, highlight a patient , click on the CIN button	CIN Form pop up dialogue opens (Y/N)
On CIN form, record treatment details e.g. Morphine given, sign form, add date and time. Save, close	Save Successful (Y/N) & CIN button turns green
Workflow 4 - Allocate yourself to a patient	
From tracking, highlight a patient. Click on the 'MO/nurse' assign button	Assign Provider pop up dialogue opens (Y/N)
Add your details, date and time then save and close	Save Successful (Y/N)
Workflow 5 – Completing nurse tasks	
From tracking, identify a request for a nurse task (nurse task column has data in it e.g. IVF, ECG, etc...)	Patient nurse request task identified (Y/N)
Record the completion of the nurse task, sign and date form (via Pt Chart > Nurse Task tab item)or (Click through by double clicking the field nurse task field). Check the completed checkbox, enter relevant conditional fields, then save and close/go back to tracking.	Save Successful (Y/N). Completed Nurse Task disappears from tracking column
Workflow 6 – Patient for admission	
From tracking, identify seen patients	Patient Identified (Y/N)
A VMO has seen a patient and wants them admitted under them (via Pt Chart > Disposition form)	Disposition form Opens (Y/N)
In the 'disposition' form record: Bed request date/time, VMO name/specialty, Special Requirements. Then save and return to tracking.	Save Successful (Y/N). Patient now appears on the admitted list (Y/N)
Workflow 7 – Finding patient information	
From tracking, pick a patient and locate the following:	
Vital signs	Identified

	(Y/N)
Presenting Problem	Identified (Y/N)
Triage category	Identified (Y/N)
Patient's NOK	Identified (Y/N)
Diagnosis	Identified (Y/N)
Clinical documentation	Identified (Y/N)
Discharge letter	Identified (Y/N)

Table 3. ED Nursing Use Cases for NEDIMS

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Appendix 2: ERP & NEDIMS Data Collection Table Templates

Time/Date	Clinician	Patient	Task	System/Paper	Time	Clicks	Pathway/Workflow	Comments

Table 1. ERP (FN) & ED staff tasks data collection table template

FN Px Code	NEDIMS MRN	Task	Time	Clicks	Pathway/Workflow	Comments

Table 2. NEDIMS data entry table template

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Appendix 3: NEDIMS Demonstration Screenshots

NEDIMS NSW Emergency Department Information Management System

ED Patient Tracking Lists

Map | +Prearrival | Reports

To Be Seen | Seen Patients | Admissions | All Patients | My Patients | Refresh | Create New Pt (Clerical) | Create New Pt (Triage)

Patients to be Seen: 10

Loc	Surname	First Name	TC	Arr	Prearrival	LOS	Age	Problem/Dx	CIN	Assign	Nurse	Pt Chart	Nurse Task	Comments	Clerk Reg	Alert
AC 11	**mortimer**	taylor	5	p		1766	32	Abdominal pain	CIN	MO/Nurse		Pt Chart			☑	
AC 2	**Josh**	Josh	3	R		1783	44	Abdominal pain	CIN	MO/Nurse		Pt Chart			☐	
Ambula	**Larsen**	Enid		a		6960	52	Abdominal pain	CIN	MO/Nurse		Pt Chart			☑	
	Berry	Blue		G		00:00	19	Abdominal pain	CIN	MO/Nurse		Pt Chart	ECGFluids		☐	
AC 2	**Howardice**	Ron	2	E		1819	47	Chest pain /	CIN	MO/Nurse		Pt Chart		Abdo CT pending	☐	
Waiting	**Joseph**	Maya	3	p		1816	29	angina	CIN	MO/Nurse		Pt Chart			☑	
AC 15	**Josh**	Braid	2	R		1800	2	testicular torsion	CIN	MO/Nurse		Pt Chart			☐	
AC 13	**highpants**	harry	2	a		1800	62	Abdominal pain	CIN	MO/Nurse		Pt Chart			☐	
AC 12	**Etxeberria**	eneko	2	d		1804	67	Chest pain /	CIN	MO/Nurse		Pt Chart			☐	
Waiting	**Thomas**	Veena	2	S		1818	27	Chest pain /	CIN	MO/Nurse		Pt Chart		this person is sleeping in the	☐	

Seen Patients: 8

Loc	Surname	First Name	TC	Arr	Prearrival	LOS	Age	Problem/Dx	Breach	MO	Nurse	Pt Chart	Nurse Task	Comments	Alert
AC 9	**PUPPY**	Very Sick		F	1221		1766	13	Abdominal pain	17666:		Nurse 1	Pt Chart			
AC 14	**Grant1**	amy	2	a	1140		1800	46	Abdominal pain	17836:	Bill		Pt Chart			
AC 5	**Bloggs**	Fred	1		0048		-	52	Abdominal pain	-	James		Pt Chart			
AC 8	**Emmadottir**	Emma		r	1224		1157:	33	Abdominal pain	991:14	Rod		Pt Chart	Serial CESerial		
AC 28	**one**	test	2	R	1337		1812	44	Abdominal pain	17859:	Team		Pt Chart	Repeat ECG		
Acute	**Johnson**	Jennifer	2	jh	1055		1831	54	angina	18483:	Rod		Pt Chart			
AC 3	**Smith**	Barry	2	c	1442		1534:	27	Chest pain /	1534:1		Nurse 4	Pt Chart			
Acute	**Hass**	Sadie	3	F	1606		1681:	61	angina	1673:1	Rod		Pt Chart			

Admitted Patients: 8

Loc	Surname	First Name	TC	Arr	LOS	Age	Problem/Dx	AMO	MO	Nurse	Nurse Task	Pt Chart	Bed Req	Ward	Comments	Clerical	Alert
AC 21	**Abrahams**	Ezekiel	1	0022	18183:	22	Chest pain /	ASU	Team		NBMIV NS 2L	Pt Chart	15/02/2011	5a	appendicitis, sepsis,	☑	
	Smith	Brian	2	0047	18182:	22	Abdominal pain	sorial	James			Pt Chart	23/02/2011		more comments for this	☑	
Resus	**Michael**	Clark	2	0026	18183:	71	Abdominal pain	Alexander	James	Lilly		Pt Chart		2f	puffy feet	☐	
	Smith	Will	5	0025	18183:	28	Chest pain /	Alexander	Rod			Pt Chart		5b		☐	
AC 6	**ME**	Triage	3	0019	18183:	105	Abdominal pain	Test	Rod			Pt Chart	06/10/2010	4b	sick patient - needs to	☑	
	peter	JAMES	3	0046	18182:	65	Limb Problem	fisher	Bill			Pt Chart				☐	
AC 11	**Rockefeller**	Barnaby	2	0047	18182:	41	Abdominal pain	bloggs	Team			Pt Chart				☑	
	Jeffries	Joan	3	0048	18182:	29	Abdominal pain	Fischer	James			Pt Chart			Is currently in the	☐	

Figure 1. NEDIMS Home/Front Page (Tracking Screen)

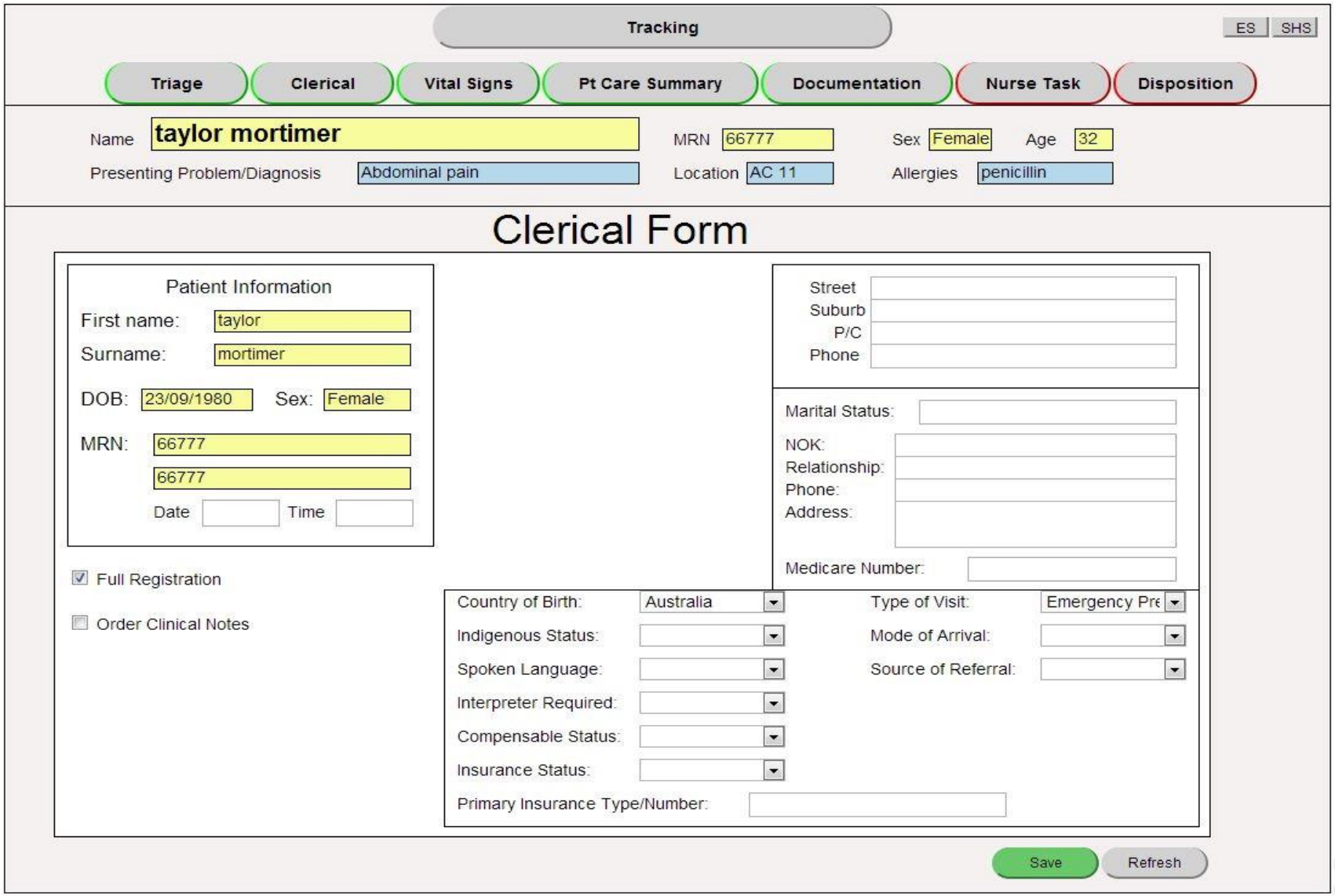

Figure 2. NEDIMS Patient Main Screen – Clerical Form

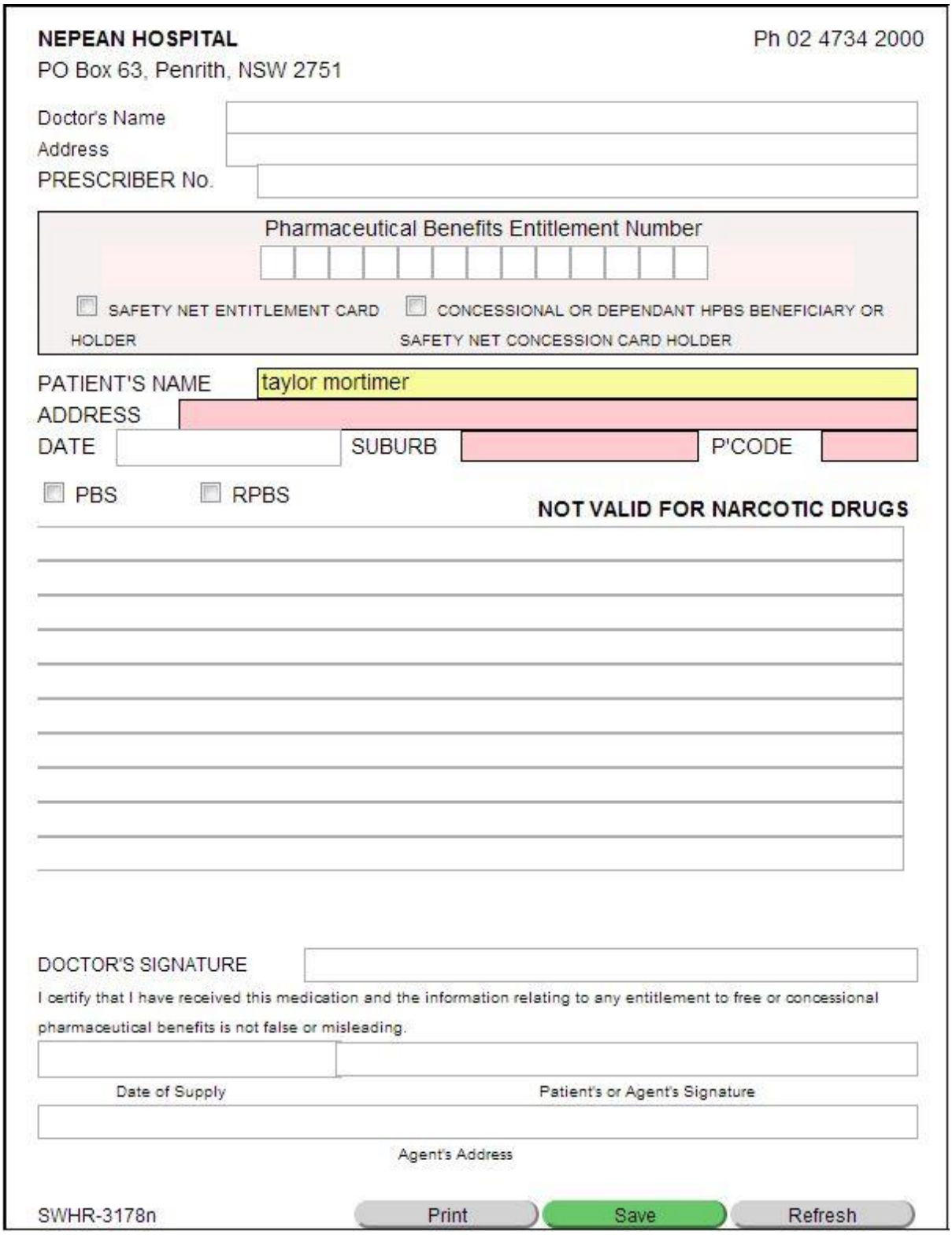

Figure 3. NEDIMS Prescription Pad (Paper form integrated into NEDIMS)