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Multi-modal Observational Assessment of Quality and Productivity Benefits From The Implementation of Wireless Technology For Out of Hours Working

John D Blakey[1]

Debbie Guy[2]

Carl Simpson[2]

Andrew Fearn[2]

Sharon Cannaby[3]

Petra Wilson[4]

Dominick E Shaw[1]

[1]Respiratory Biomedical Research Unit, University of Nottingham, Nottingham, UK

[2]City Hospital Campus of Nottingham NHS University Hospitals NHS Trust, Nottingham, NG5 1PB, UK

[3]Head of Health Sector Policy, Association of Chartered Certified Accountants, 29 Lincoln's Inn Fields, London, WC2A 3EE, UK.

[4]European Health and Care Team, Internet Business Solutions Group, Cisco Systems, Brussels, Belgium.

Corresponding author:

Dr Dominick Shaw

Dominic.shaw@nottingham.ac.uk

Respiratory Biomedical Research Unit, Clinical Sciences Building, City Hospital Campus, Nottingham, NG5 1PB.

Tel: 0115 8231709

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Fax: 0115 8231946

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SUMMARY

Article Focus

Can an out of hours wireless task requesting and tracking system improve quality and safety in secondary care?

Key Message

The widely adopted Hospital at Night system for out of hours working is inefficient and risks introducing error. We introduced a wireless task requesting and tracking system and showed this change was acceptable, and improved qualitative and quantitative markers of efficiency and safety.

Strengths and Limitations

The study showed clinically meaningful and statistically significant positive changes using a variety of complementary assessments. The study was observational and within a single acute NHS Trust.

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ABSTRACT

Background

Providing out of hours care in hospital is challenging as staff are few and often geographically dispersed. Most NHS hospitals rely on a landline phone and pager system with a co-ordinator matching tasks to healthcare professionals. However, this system is inefficient and may contribute to untoward incidents. We investigated if a wireless system of call handling and task management for out of hours care could replace the pager system and improve efficiency, patient safety, and staff satisfaction.

Methods

We used quantitative and qualitative methods, including interviews with staff, a standard satisfaction questionnaire, independent observation, data extraction from work logs and incident reporting systems, and analysis of hospital committee reports to compare the different task handling systems in secondary care in Nottingham.

Results

Users were more satisfied with the new system (satisfaction score 62/90 vs. 82/90, p=0.0080). With the new system over 70 hours per week of co-ordinator time was released, and there were fewer untoward incidents related to handover and medical response (OR=0.30, p=0.02). Broad clinical measures (cardiac arrest calls for peri-arrest situations and length of hospital stay) improved significantly in the areas covered by the new system.

Conclusion

The introduction of call handling software and mobile technology over a medical grade wireless network improved staff satisfaction with the Hospital at Night system. Improvements in efficiency and information flow have been accompanied by a reduction in untoward incidents, length of stay, and peri-arrest calls

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BACKGROUND

Care for patients in hospital is broadly divided into "in hours" which comprises Monday to Friday between 9am and 5pm, and "out of hours" (OOH) which comprises the remainder of the week and public holidays. Patients are therefore subject to out of hours care for three quarters of the year. Out of hours care in the NHS and many other systems is normally provided by junior staff with seniors supporting from home on request. Over the past decade, there has been both a reduction in junior doctors' working hours and an increase in the amount of clinical work both generally[1] and out of hours[2]. Locally in Nottingham, we have seen yearly admissions rise by almost 25000 (15%) between 1999-2000 and 2010-11[3] whilst individual junior doctor's hours have fallen by more than 35% to comply with the European Working Time Directive. As a consequence of this directive, it became apparent that changes to the traditional on-call system were required to maintain patient safety. In response, the Hospital at Night (H@N) project was initiated and adopted nationally[4]. Although the H@N solution is confined to the UK, the issue of maximizing limited clinical resources out of hours is common to almost all secondary healthcare systems and local solutions outside the UK share many of the same features. The issue also arises with non-medical staff, as other healthcare and support professionals such as radiographers or physiotherapists are usually fewer in number and cover a greater area than in normal working hours.

H@N projects intend to achieve safe clinical care using teams comprising junior doctors, nurses and clinical support workers to provide OOH cover. All requests for patient-related tasks from ward nurses are directed through a co-ordinator, usually a senior nurse, who provides a triage function and allocates tasks to team members. This national initiative is intended to deploy a co-ordinated team that improves efficiency in resource management, particularly allowing medical staff more time to engage in clinical activity. The exact composition of the team varies between hospitals dependent on the composition and volume of the workload and local policy, though all should be risk assessed using standard tools[5]. An initial assessment of the impact of H@N implementation in 2005[4] suggested H@N was as safe as other forms of care. However, subsequent government reports showed both staff numbers and the ratio of staff per bed were higher following implementation of the H@N system [6 7].

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ASSESSMENT OF THE PROBLEM

Nottingham University Hospitals NHS Trust serves 2.5 million people and employs over 13000 staff managing 1700 beds. These beds are divided approximately equally across two sites, Queen's Medical Centre and Nottingham City Hospital (NCH). The H@N service at NCH for out of hours care was introduced in 2006 As with most hospitals, H@N was based around a landline phone and pager system, with requests phoned from the ward to the coordinator and then passed onto the junior doctor or clinical assistant by phone. Two internal reports were conducted after informal concerns were raised over the H@N service[8 9] and their findings are summarised below:

As NCH covers 46.3 hectares and patients enter via eight different specialty admission points, locating the nearest phone was often time-consuming for junior doctors who were in transit across the site. The number they responded to was also often engaged due to the volume of calls. This led to delays in calls being answered, and potential delay in clinical action being taken. The co-ordinator introduced as part of the national H@N initiative spent their shift answering and making phone calls from an office rather than providing senior nursing input. This repetitive role with minimal clinical contact had a negative impact on their morale. These frequent calls also interrupted clinical care provided by doctors and nurses, as they have been shown to do in other settings[10].

It became apparent in Nottingham, as it did nationally, that the H@N service was limited by issues around task allocation and impaired communication between team members[8]. The passing of clinical information from one team to another (handover) is a particular area of concern[11 12], is something junior doctors feel ill-prepared to do[13] and is frequently done rapidly and inaccurately[14 15].

The H@N system also highlighted issues with transcription of information: Each junior made notes on loose paper when calls were received, and these were sometimes very brief because pressing clinical matters curtailed conversations. Should the paper be lost or damaged, or the information be noted inaccurately, basic details could be difficult and time-consuming to reassemble. At the end of a shift, doctors often took their notes home rather than disposing of them as confidential waste or filing them in patient records, with attendant information governance issues. These issues have also been highlighted as

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sources of error outside the NHS[16]. Verbal handover and hand-written records also led to a difficulty in assessing what actual work was being completed in each shift and by whom, meaning little information was available for workforce planning and feedback to in hours care regarding tasks that should have been completed during that period (e.g. drug card rewrites, warfarin prescribing).

The installation of a Medical-Grade Network (Cisco Systems, San Jose, USA) across the University Hospitals Nottingham NHS Trust sites afforded the opportunity to introduce a secure wireless communications system for H@N. We worked with an industry collaborator (NerveCentre Software, Wokingham, UK) to design and implement a software system to promote efficiency and reduce risk within H@N. The software builds on components from the "borderless" and "collaboration" aspects of the Cisco network and the power and connectivity of the wired components.

All tasks are now logged on to ward-based desktop PCs using the standardised and validated "SBAR" (Situation-Background-Assessment-Recommendation) format [17-19] recommended by the NHS Institute for Innovation and Improvement (http://www.institute.nhs.uk/). The task is then sent wirelessly to a coordinator who carries a small tablet PC weighing 0.5kg. This task can then be triaged and allocated wirelessly to the most appropriate team member (the co-ordinator included). Tasks are relayed to junior doctors and support workers via a message to dedicated on-call mobile phones (see figure one). The recipient accepts the task with a single button press and it is added to the freely accessible task list held on their phone. Once a task is passed to a junior doctor and accepted it stays active on both their and the co-ordinator's list until completion or reassignment to another individual. The system allows task prioritisation with jobs labelled as green, amber or red depending upon clinical need (see supplementary material). All "red" tasks are copied to a phone carried by the middle grade doctor so they are aware of all potentially serious problems and can attend to assist or review as necessary. Pagers are now only carried by the cardiac arrest team as a fail-safe.

We set out to assess the effect of the implementation of this new system on staff satisfaction, information flow, and broad clinical outcomes.

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METHODS

We drew on the European Commission funded Model for Assessment of Telemedicine[20] and the proposals of Westbrook and colleagues[21] to inform our study methodology. This paper focuses on staff satisfaction and patient safety outcomes at NCH.

Review of Untoward Incidents

Two authors (DES and JDB) reviewed all clinical incidents that had been reported in accordance with NHS policy via Datix software (Datix Ltd, London, UK) in the Medical Directorate over two periods of two months preceding (January and February 2011) and subsequent to (June and July 2011) the introduction of the new task allocation system. We chose these two month periods as the total number of reported incidents was identical. We selected the incidents that occurred out of hours and were related to handover of information or job allocation. In the case of disagreement, arbitration was undertaken by a third author. The proportion of calls related to slow response of the H@N service or handover to or within the H@N service were compared by Chi-square test. We acknowledge that incidents are traditionally under-reported in secondary care and as such the aim of this analysis was to ensure the new system did not introduce any major new issues.

The number and directorate location (covered by H@N or not) of cardiac arrest calls placed at Nottingham City Hospital were recorded for a six month period (February to July) in 2010 prior to the introduction of H@N, and for the equivalent period one year later. We recorded an "actual arrest" where CPR or defibrillation or intubation was required as recorded on the Trust's standard cardiac arrest call audit form. "Urgent calls" were those where assistance was required with an unwell patient. Three genuinely false calls requiring no medical intervention were discounted. The numbers of calls per month before and after the new system was introduced were compared by Mann-Whitney test.

Staff Interviews and Observation

To assess the overall impact of the new system on staff satisfaction we undertook observation of, and non-directive interviews with, a purposive sample of H@N co-ordinators, junior doctors using the system, senior doctors, ward nursing staff, and Trust management. A brief and flexible interview framework was agreed to elicit opinion and experiences regarding advantages or problems with the two systems for use out of hours, information handover, and the impact of the changes on the Trust generally. We also asked 20 users (5

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junior doctors, 5 co-ordinators, 5 ward nurses, and 5 clinical support workers) selected in a quasi-random fashion (by day of week on shift) to complete a modified version of the IBM Computer System Usability Questionnaire[22] before and after the introduction of NerveCentre software and wireless devices. These non-normally distributed paired data were analysed by Wilcoxon signed rank test.

H@N Co-ordinator Activity

To assess the impact of the new system on the activity of the H@N coordinator, we recorded their activity for one week prior to its introduction (in March 2010), and again for a week one year later. The parameters recorded were: The time spent by H@N co-ordinator on direct clinical care, the number of phone calls made and received, the time spent on logging and distributing tasks, the time spent giving telephone advice, and the number of tasks assigned whilst away from their desk. The change in these parameters with the introduction of NerveCentre was assessed by t-test.

Length of Stay Statistics

We assessed the weekly mean of lengths of stay for six months prior to the introduction of the new system (February to July 2010) and for the same six months in 2011 using centrally collated Trust statistics. The lengths of stay were compared by Mann-Whitney test.

RESULTS

Review of Untoward Incidents

In both two month periods there were 552 electronically reported incidents. Of these, the majority related to patients falls (see supplementary figures three and four for a detailed breakdown). On systematic review of all 1104 incidents, we found 17 to be related to inadequate or absent handover, or to a slow response of H@N, which resulted in actual patient harm or required remedial action to prevent this. 13 of these occurred prior to wireless working and 4 after its introduction. Exposure to wireless working was therefore associated with a reduction in the proportion of incidents that were attributable to the H@N system (OR=0.308, p=0.028 by Chi-square test).

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During the study periods, there was no change in the overall number of cardiac arrest calls placed at the NCH site (median 22.5 per month before and 21 after, p=0.973) though the total number of arrest calls for the Trust as a whole increased significantly (from 57.5 to 72 per month, p=0.041). In the initial six months 26% of cardiac arrest calls placed within the area covered by H@N were to obtain help with patients who had not arrested. This proportion fell significantly to 11% after the new system was implemented (p=0.015).

Interviews

Three main themes repeatedly arose from the interviews and concerned the satisfaction of staff with the old H@N system, concerns over resource management, and concerns over the accuracy of information transcription.

Satisfaction of Staff with Their Role in the H@N system

All grades and professions reported a step change in their satisfaction with the H@N system. This was largely attributable to the facilitation of communication resulting in a marked increase in the time individuals spent undertaking tasks for which they felt they had been trained. The H@N co-ordinators felt this change most acutely, one saying simply:

"*It has given me my job back*" (H@N co-ordinator)

Other co-ordinators were similarly enthused to be released from overwhelming administrative duties:

"*The system required you to be on the computer all the time. I didn't like that. I'm not a computer person; I'm a hands-on clinical person*." (H@N co-ordinator)

Many said that they were considering or actively seeking alternative employment before the new system was implemented:

"*I wouldn't have stayed in this job if thing's hadn't changed. I would have left*." (H@N co-ordinator)

Frustration was not confined to the nursing staff, with middle grade doctors conveying their disenfranchisement with the hospital at night system, sometimes in explicit language not reproduced here.

"*Initially we used to know what was going off* [patients who are ill]*. Hospital at Night put a barrier between the reg* [middle grade] *and the rest of hospital. Having the Blackberry*

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[mobile phone] *does make a difference. I can finally get hold of someone quickly to give advice or to let them know if I've got stuck on labour suite or somewhere."* (Middle grade)

Resource Management

A recurring theme in the old system was that all pages that co-ordinators or junior doctors received appeared equally important until answered, and the process of answering pages from wards was time-consuming. A co-ordinator explained she was often receiving pages faster than they could be answered, without knowing which to call back as a priority:

"(we) would write down the phone numbers and work through them one by one. For each number we would call the ward, and then bleep [page] *the doctor .... which could take ten minutes if the doctor was not near a phone or was busy."* (H@N co-ordinator)

It was also only by paging doctors or support workers that the co-ordinator could assess if they had completed their tasks, risking introducing additional delays.

"We had no idea when a doctor had completed a task or how long they are with a particular patient. If we page them we often take them away from the patient." (H@N co-ordinator)

A ward sister commented that nurses placing bleeps grew frustrated with delays in obtaining a response and spent valuable time re-contacting the co-ordinator to ensure the task was treated appropriately:

"the efficiency of the new system, with nurses not needing to chase doctors, means nursing staff can spend more time with patients" (ward nurse)

Junior doctors were impressed at the reduction in time and inconvenience as the need to be bleeped greatly diminished. They also were relieved that their workload could be accurately monitored, improving the coordinators ability to distribute work evenly.

"I can easily contact the H@N co-ordinator, and she can see my outstanding workload at any time. It has taken away the worry that I'm leaving patients waiting." (Junior doctor)

Senior doctors also had grown concerned with their inability to assess what actual work was being done by their juniors. Their perspective tended to be concern over potential medico-legal issues..

*"Tasks range from the simple, rewriting a drug card, to the complicated, organizing a brain scan for a critically unwell unconscious adult at 4am....Our system did not accurately capture the breadth and depth of the complexities involved." (*Medical consultant*)*

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The Transcription of Information

A major issue with the previous hospital at night system was the concern over the repeated verbal transfer of limited information. There was enthusiasm for the change in practice the new system has facilitated:

*"It's great how the new system categorizes everything. It forces you to provide all the necessary information so that the doctor is properly prepared and turns up at the right place at the right time with the right patient details" (*Ward sister*)*

Junior doctors expressed additional concerns over their own transcription of patient details when paged whilst busy, and their fear of losing their job list:

*"I must have noted down the wrong name so I couldn't find the patient. I kept phoning the hospital at night co-ordinator but the phone was engaged so I just handed the job back at the end of the shift." (*Junior doctor*)"Love the fact that I don't need to carry paper around. There is no risk anymore that I'll lose my patient list" (*Junior doctor*)*

As the H@N team is staffed by individuals in training posts, they are required to log the cases they see and the procedures they undertake. Few, if any, had time to prepare an anonymised second list to complement their job sheet. As a list of tasks they completed can now be emailed to each doctor at the end of the shift, this pressure has been removed.

*"It was incredibly difficult to document the experience gained at night" (*Junior Doctor*)*

Other comments that were repeated concerned the benefits in terms of reduced noise on the wards given the reduced need to make and receive phone calls, and the great potential the project had for monitoring and planning out of hours care in the future.

Satisfaction survey

Staff satisfaction with the H@N system itself improved significantly (p=0.008, Wilcoxon signed rank test) from a median score of 62 (maximum possible = 90) with the pager-based system to a median of 82 with the NerveCentre wireless technology system (see table one). The minimum response score for each category improved markedly such that no-one recorded less than 8 out of ten for their overall satisfaction with the system.

H@N Coordinator Activity

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Over the periods studied, the total number of tasks per shift assigned by the H@N co-ordinator did not differ significantly (weekly total 1280 vs. 1379, comparison by tasks allocated per shift p=0.695). However, the number of tasks assigned to a team member whilst the co-ordinator was at their desk dropped sharply (weekly total 1280 vs. 99, $p<10^{-36}$). The time spent receiving and logging calls during each shift also fell markedly (see figure two) from a median (IQR) of 97% (4.32) of total shift time to 42% (27.47) of shift time ($p<10^{-36}$). Commensurate to the decrease in time spent on the telephone and the ability to assign tasks away from their desks, co-ordinators were able to begin to engage in clinical care. Direct clinical care time increase from a baseline of zero to a median (IQR) of 56% (28.14) of shift time.

Length of Stay Statistics

The median length of stay on medical wards covered by NCH H@N was 6.50 days (n=839 in-patient stays) in the study period in 2010 and 5.67 days (n=739) in 2011 (P=0.004 by Mann-Whitney test). The median length of stay on other wards which were neither day-case units nor covered by NCH H@N was 2.90 days (n=1279 in-patient stays) in the study period in 2010 and 2.67 days (n=1254) in 2011 (P=0.263).

DISCUSSION

In this study, we describe the implementation of a wireless system that allows task request, allocation, and management on handheld devices for out of hours care. Our evaluation of the new hardware and software reviewed aspects of patient safety, utilisation of resources, and staff satisfaction by comparing operational processes before and after implementation.

The implementation of wireless working was extremely well received by all users with particular praise for the improvements in task-flow efficiency and information governance achieved. The H@N co-ordinators reported feeling liberated by the system and are spending vastly greater time engaged in direct clinical activity. A further marker of this is that long-standing vacancies for co-ordinator posts have now been filled. Although causality cannot be inferred, broad clinical measures such as length of stay and cardiac arrest calls placed for unwell patients fell significantly with the change in H@N system supporting at least clinical non-inferiority of new method.

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Wireless systems similar to the one described here are not yet commonplace in secondary care in Europe, although limited computerized handover systems have shown the potential for patient benefit[23 24]. Early adopters in other countries have seen improvements in clinical outcomes not only using a network to manage information passing within clinical teams, but also to track over pieces of equipment using radio-frequency identification tags[25 26] and with electronic nursing records[27]. Limited data on the use of push e-mail to support current practise also exists[28]. However, these initiatives tend to be adjuncts rather than replacements for current systems, and they are usually generic rather than tailored for purpose so do not include a standard data entry format with automatic population of fields and drop-down menus, and they do not automatically grade the urgency of communications.

Wireless technology also has the potential to allow advanced patient monitoring which can improve patient outcomes[29 30] and save money[31]. We see also potential for this system to collect data which will highlight wards where routine tasks are not completed in hours, to monitor the performance of different composition of out of hours teams of junior doctors, and to add clinical parameters to a dashboard of Trust performance. As the mobile devices are able to record the location of the users indoors and out, there is also scope for time and motion study to further increase efficiency. The wider applicability of an approach such as this to any group of individuals addressing complex and dynamic tasks with limited and geographically dispersed resources has also become apparent. Locally, portering and critical care outreach services have adopted a similar system for in-hours working, and it is being revised to manage personnel staffing emergency theatre lists and their liaison with ward nurses.

There is clearly a difficulty in assessing the impact of complex service delivery interventions such as the one described. It is practically extremely challenging to undertake a randomised trial of the system described as few centres have an appropriate network and it would require a considerable investment in equipment and staff training. Furthermore, one major flaw in the traditional pager system is its inability to accurately record activity. It is therefore difficult to assess the impact of the system at a ward or patient level as detailed information is only available post-introduction. We also acknowledge that we did not systematically record nurse and physician activity before and after implementation in the same way as was undertaken for the co-ordinators. Although the introduction of the new wireless working was associated with improvement in broad clinical measures we also

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emphasize that this single centre observational study cannot prove causality. Future studies are needed to assess any benefits on patient safety or length of stay.

A major barrier to the implementation of this potentially highly productive system is cost, a factor influential in the design of H@N services nationally[32]. The total cost of the software purchase and deployment across both Trust sites, and the additional hardware required for the project (40 phones for junior doctors and clinical support workers and 4 tablet computers for co-ordinators) was less than £150000. However, early indications are these costs will be offset relatively rapidly by the improved workforce planning facilitated by the system, by the reduction in delayed discharges or procedures, and through fewer untoward incidents.

Wireless technology and securely held electronic data have become a central part of daily life outside the NHS. In this paper we present an acceptable way of introducing such technology to address some of the issues common to Hospital at Night systems: we found it to be welcomed by users, efficient, and be correlated with improved broad clinical outcomes.

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TABLES

Table 1 – Comparative satisfaction of users of the old and new H@N systems. Scores are median values for 20 staff members (5 junior doctors, 5 H@N co-ordinators, 5 clinical support workers, and 5 ward nurses) for a modified version of the IBM Computer System Usability Questionnaire[22].

Statement	Old System		New System	
	Median	Minimum	Median	Minimum
Overall I am satisfied with how easy it is to use the system	7	1	9	7
It was easy to learn to use the system	9	1	10	5
The system takes little of my time allowing me to spend more time with patients	6	1	10	7
The system allows information on the patient to be accurately recorded	5	0	10	7
I feel comfortable using the system	8	1	10	7
Whenever I make a mistake using the system I recover quickly and without impact to safety	8	1	9	7
The organisation of information on the screens is clear	6	1	9	7
I like using the interface on this system	6	0	9	5
Overall, I am satisfied that the system effectively supports my job	7	0	9	8
TOTAL SCORE n	62		85	

FIGURE LEGENDS

Figure One: Flow of Information for One Request Under The Two H@N Systems

Figure Two: Box plot showing the percentage of H@N co-ordinator time spent logging and allocating tasks across shifts in comparable weeks in March 2010 and 2011, before and after the introduction of NerveCentre and wireless technology.

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COMPETING INTERESTS

PW is employed by the manufacturer of the medical grade network used in this study (Cisco Systems). The other authors have no conflict of interest to declare. The commercial entities Cisco Systems and NerveCentre Software had no role in the design and execution of analyses, and were not permitted access to patient identifiable data.

AUTHOR CONTRIBUTIONS

DES, SC, PW, AF, and JDB conceived of the ideas for study. DES, AF, and JDB designed the study. DG, SC, and PW undertook non-directive interviews and administered the questionnaires. CS collected and compiled data on cardiac arrest calls. AF and JDB acquired the clinical data. JDB, DES, and DG reviewed the incident reports. JDB undertook the analyses. JDB and DES drafted the manuscript which all authors approved.

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DATA SHARING

Supplementary data is available as indicated in the body of the manuscript.

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REFERENCES

1. Peacock PJ, Peacock JL, Victor CR, Chazot C. Changes in the emergency workload of the London Ambulance Service between 1989 and 1999. *Emerg Med J* 2005;22(1):56-9.
2. Thompson C, Hayhurst C, Boyle A. How have changes to out-of-hours primary care services since 2004 affected emergency department attendances at a UK District General Hospital? A longitudinal study. *Emerg Med J* 2010;27(1):22-5.
3. HESOnline: Hospital Episode Statistics. *NHS Health and Social Care Information Centre*, 2011.
4. Mahon A, Harris C, Tyrer J, Carr S, Lowson K, Carr L, et al. The implementation and impact of Hospital at Night projects. In: Department_of_Health, editor. London: Crown, 2005.
5. NPSA. Hospital at Night - Patient Safety Risk Assessment Guide. Department_of_Health, , 2005.
6. NHS_Workforce_Projects. Model Hospital at Night Team: 2007 Survey Findings.: Department_of_Health, 2008.
7. NHS_Workforce_Projects. The Case for Hospital at Night - The Search for Evidence. Department_of_Health, 2011.
8. Teahon K. Report on a Study of May 2009. *Medical Out of Hours Service City Campus* University Hosptials Nottingham NHS Trust, 2009.
9. Wallace S, McKinnin S, Guy D. External Review of Hospital at Night. *Medical Out of Hours Service City Campus*: University Hosptials Nottingham NHS Trust, 2010.
10. Katz MH, Schroeder SA. The sounds of the hospital. Paging patterns in three teaching hospitals. *N Engl J Med* 1988;319(24):1585-9.
11. Bywaters E, Calvert S, Eccles S, Eunson G, Macklin D, McCullough C, et al. Safe Handover: Safe Patients: British Medical Association, 2004.
12. Rabol LI, Andersen ML, Ostergaard D, Bjorn B, Lilja B, Mogensen T. Descriptions of verbal communication errors between staff. An analysis of 84 root cause analysis-reports from Danish hospitals. *BMJ Qual Saf* 2011;20(3):268-74.
13. Cleland JA, Ross S, Miller SC, Patey R. "There is a chain of Chinese whispers ...": empirical data support the call to formally teach handover to prequalification doctors. *Qual Saf Health Care* 2009;18(4):267-71.
14. Tokode M, O'Riordan B, Barthelmes L. "That's all I got handed over": missed opportunities and opportunity for near misses in Wales. *Bmj* 2006;332(7541):610.
15. Sithamparanathan M. Personal views - "That's all I got handed over". *Brit Med J* 2006;332(7539):496-96.
16. Volpp KG, Grande D. Residents' suggestions for reducing errors in teaching hospitals. *N Engl J Med* 2003;348(9):851-5.
17. Haig KM, Sutton S, Whittington J. SBAR: a shared mental model for improving communication between clinicians. *Jt Comm J Qual Patient Saf* 2006;32(3):167-75.
18. Hohenhaus S, Powell S, Hohenhaus J. Enhancing Patient Safety During Hand-Offs: Standardized communication and teamwork using the 'SBAR' method. *American Journal of Nursing* 2006;106(8):72A-72B.
19. Beckett CD, Kipnis G. Collaborative communication: integrating SBAR to improve quality/patient safety outcomes. *J Healthc Qual* 2009;31(5):19-28.
20. Kidholm K, Bowes A, Dyrehauge S, Ekeland AG, Flottorp SA, Jensen LK, et al. The MAST Manual: Model for Assessment of Telemedicine, 2010.
21. Westbrook JI, Braithwaite J, Iedema R, Coieraa RW. Evaluating the impact of information communication technologies on complex organizational systems: a multi-disciplinary, multi-method framework. In: Fieschi M, editor. *Studies in Health Technology and Informatics*. Amsterdam: IOS Press, 2004:1323-27.

For peer review only

22. Lewis JR. Ibm Computer Usability Satisfaction Questionnaires - Psychometric Evaluation and Instructions for Use. *Int J Hum-Comput Int* 1995;7(1):57-78.
23. Raptis DA, Fernandes C, Chua W, Boulos PB. Electronic software significantly improves quality of handover in a London teaching hospital. *Health Informatics J* 2009;15(3):191-8.
24. Ryan S, O'Riordan JM, Tierney S, Conlon KC, Ridgway PF. Impact of a new electronic handover system in surgery. *Int J Surg* 2011;9(3):217-20.
25. HIAE. Hospital Israelita Albert Einstein Protocols. Sao Paolo, 2011.
26. Cisco-Systems. Brazilian Hospital Deploys Innovative Services. *MGN Consumer Case Studies*, 2011.
27. Lindgren CL, Elie LG, Vidal EC, Vasserman A. Transforming to a Computerized System for Nursing Care Organizational Success Within Magnet Idealism. *Cin-Comput Inform Nu* 2010;28(2):74-78.
28. O'Connor C, Friedrich JO, Scales DC, Adhikari NK. The use of wireless e-mail to improve healthcare team communication. *J Am Med Inform Assoc* 2009;16(5):705-13.
29. Abraham WT, Adamson PB, Bourge RC, Aaron MF, Costanzo MR, Stevenson LW, et al. Wireless pulmonary artery haemodynamic monitoring in chronic heart failure: a randomised controlled trial. *Lancet* 2011;377(9766):658-66.
30. Lilly CM, Cody S, Zhao H, Landry K, Baker SP, McIlwaine J, et al. Hospital mortality, length of stay, and preventable complications among critically ill patients before and after tele-ICU reengineering of critical care processes. *JAMA* 2011;305(21):2175-83.
31. Leong JR, Sirio CA, Rotondi AJ. eICU program favorably affects clinical and economic outcomes. *Crit Care* 2005;9(5):E22.
32. Hospital at Night Baseline Report: NHS, 2006.

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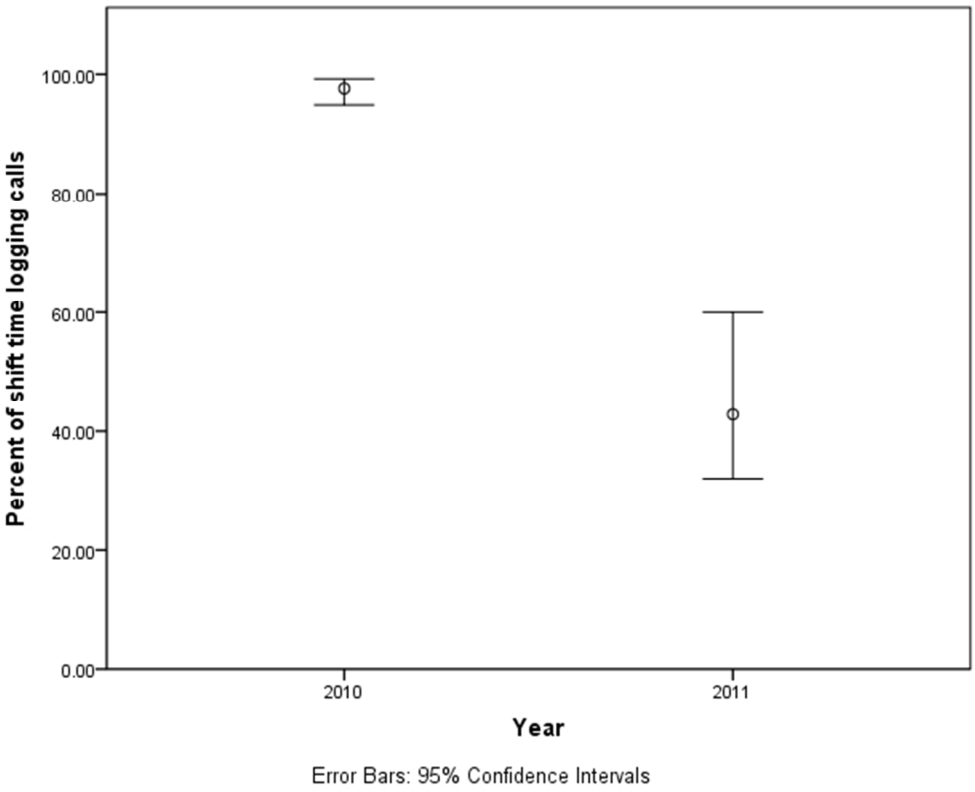

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Supplementary Information for Wireless Working Paper

SI1: Classification of Jobs By Priority

A "clinical review/management" task is available for all categories so additional tasks not listed here can be assigned at the discretion of the co-ordinator

RED
Critically ill/Immediate response
Early warning score (standard score based on routine observations) >4
Urgent admission
Chest pain
Fall where patient has suffered major injury or changed Glasgow Coma Scale by 2 points
Neutropenic sepsis
Acutely unwell/Urgent response
Cardiac arrest
Sudden onset of breathlessness

AMBER
Post operative bleeding
Wound dehiscence
Confused
Drug administration
ECG interpretation

GREEN
Abnormal blood results
Clerking
Certification of death
Drug prescribing
Microbiology
Cannulation
Catheterisation
Venepuncture
X ray review
IV fluids prescribing
Discharge
Assessment post fall
ECG recording
Liaison with other services
Advice to nursing/junior staff
Blood results interpretation
Discussion with relatives

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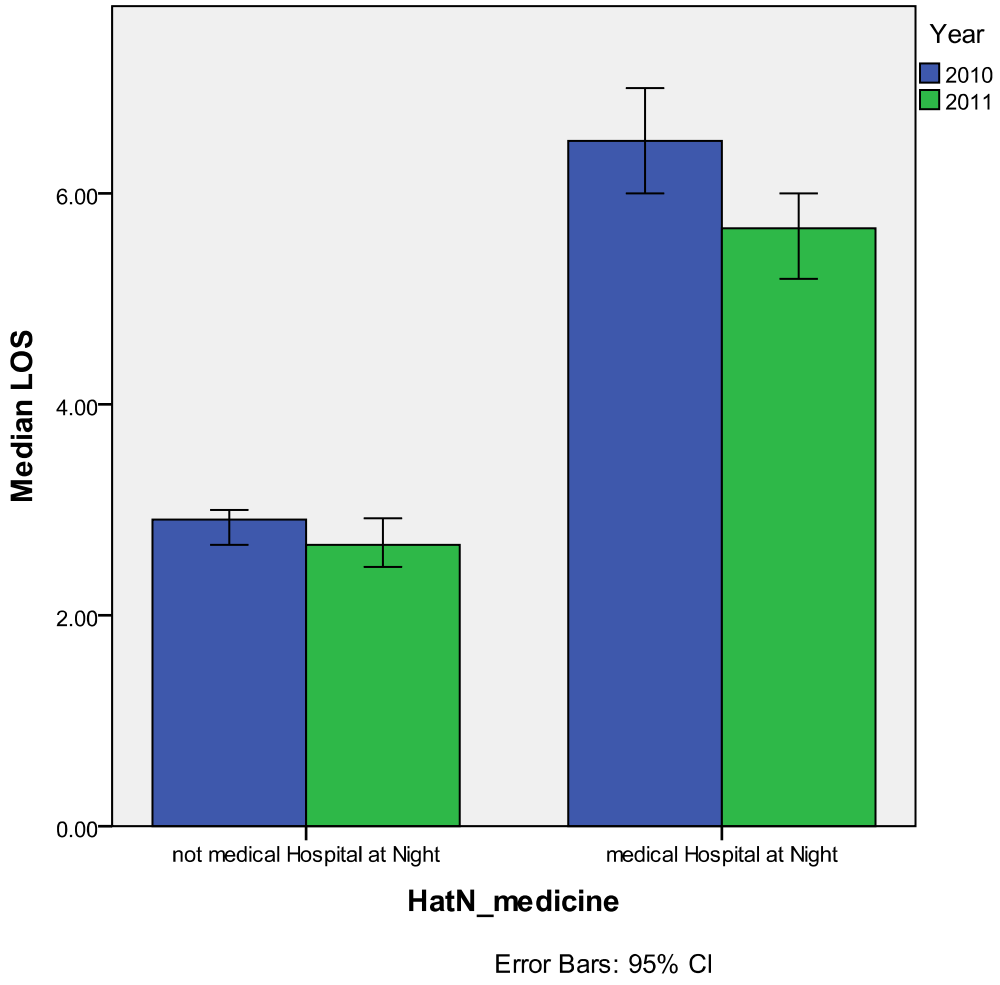
Supplementary Item 2: Bar chart showing the median Length of Stay at Nottingham City Hospital before and after the introduction of a wireless out of hours working system.



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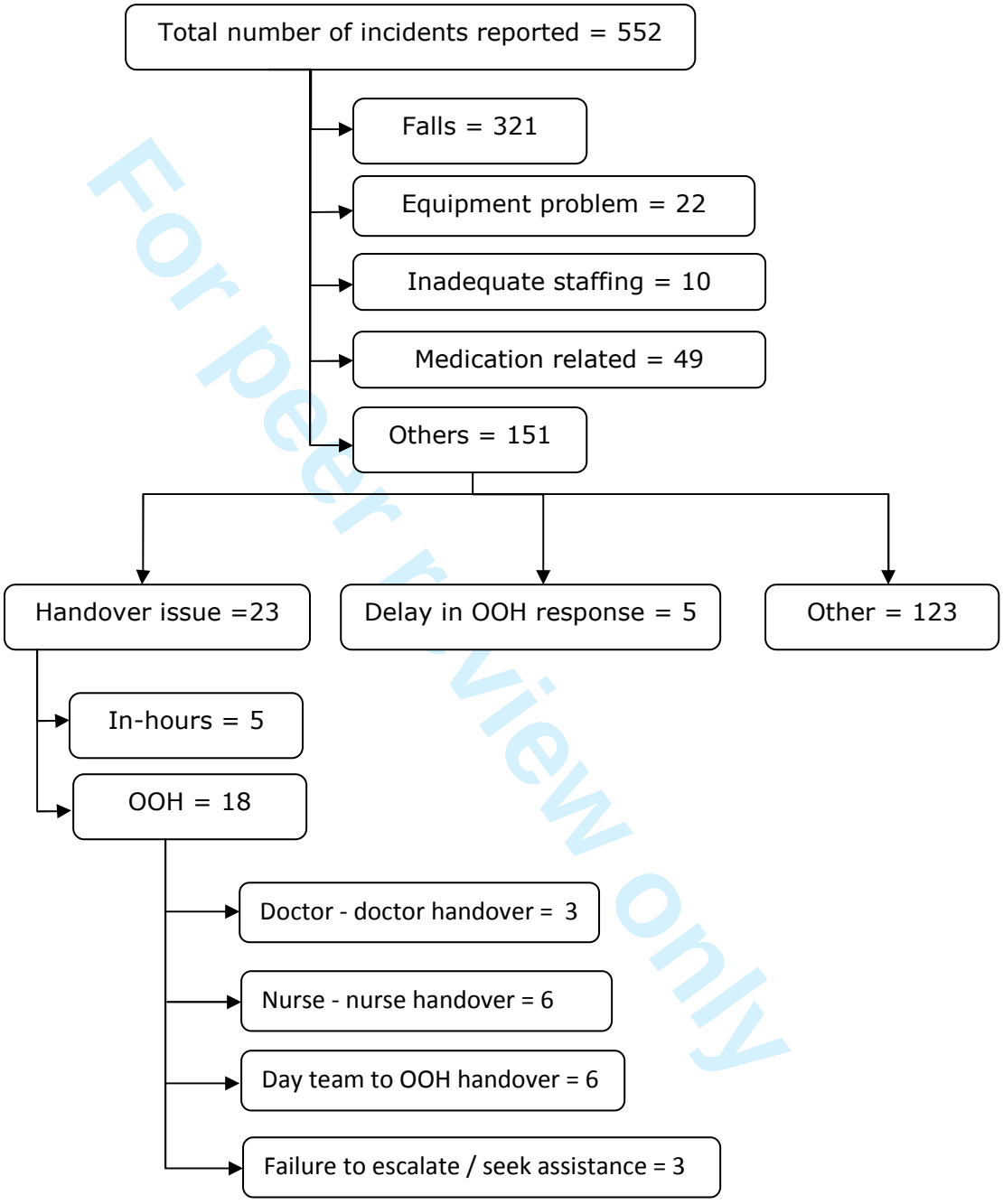
Supplementary Item 3: Incidents reported in the medical directorate in January and February 2011.



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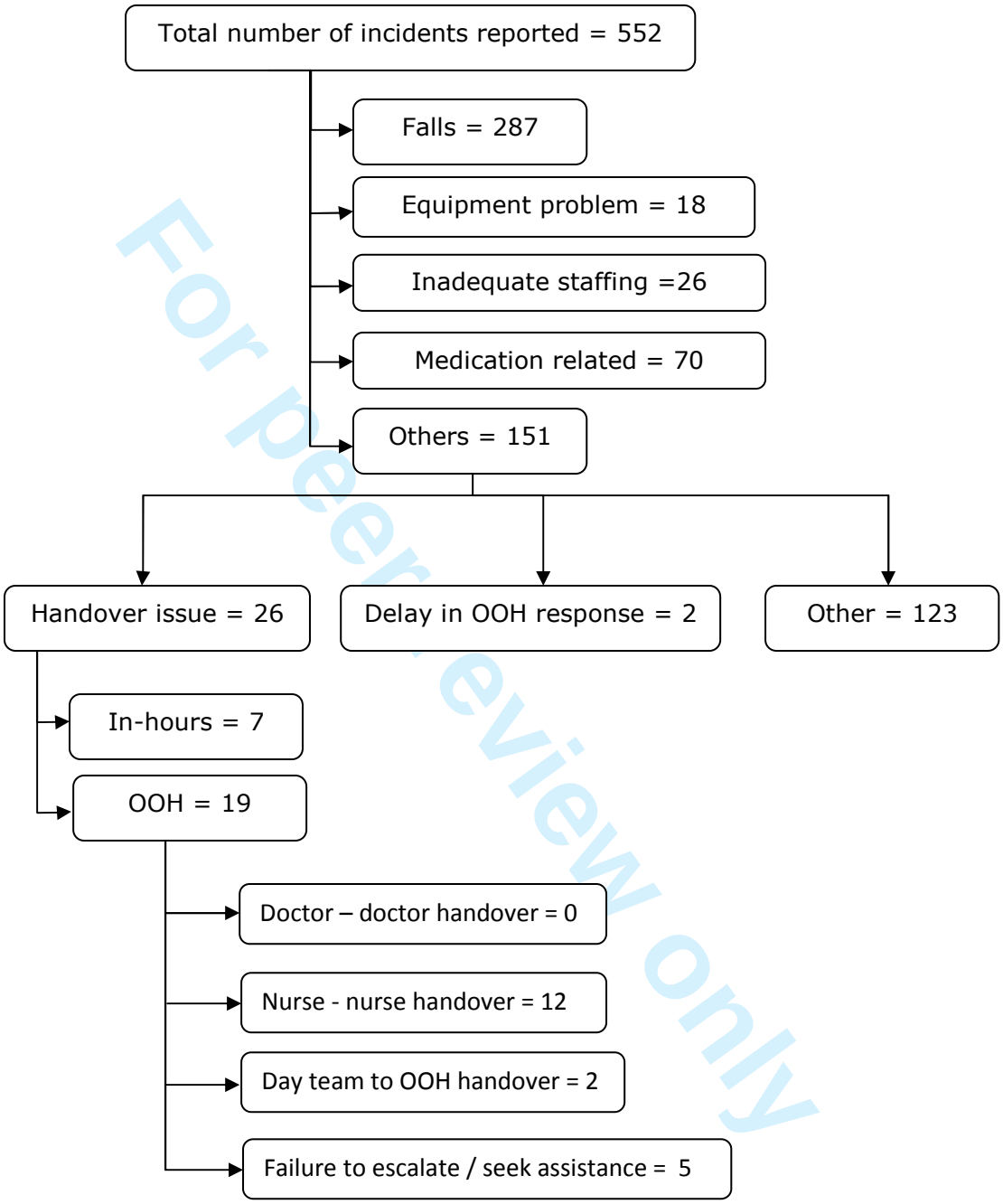
Supplementary item 4: Incidents reported in the medical directorate in June and July 2011.



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Supplementary Item 5: Examples of Untoward Incidents Where the New H@N System Could Have Reduced Patient Risk

The following are anonymised and abbreviated accounts of clinical incidents that occurred within Nottingham University Hospitals NHS Trust before the implementation of the wireless H@N system, yet may have been prevented by its earlier uptake.

Example 1- Job allocation issue

An 80 year old lady was awaiting discharge on a Saturday having been admitted seven days previously; she was on warfarin for atrial fibrillation but initially her INR had been high following a change in her medication. The ward staff were waiting confirmation that her INR was within range, her discharge medication to be prescribed, and for her next two doses of warfarin to be dosed prior to discharge. The INR had been rechecked at 5pm and the job passed over to the H@N team to chase. The nurses bleeped the H@N coordinator at 8pm, and the coordinator allocated the job to a junior doctor. That junior doctor denied any knowledge of the task being passed on to them. It was midnight by the time the oversight was identified and addressed. Although the patient's INR was appropriate for discharge, the transport slot was missed and the patient had to spend another night in hospital.

Potential with the New System

In this situation the nurse logs the job on the ward computer. The job gets passed electronically to the coordinators tablet PC where it is allocated to the junior doctor covering that area or with the lightest job load. Once the coordinator accepts and allocates the job to the junior doctor the job is highlighted on the nurse's computer as accepted and pending. If the job is not processed by the time of the doctors' shift change the job remains live on the system, and must therefore get passed on. The job is only deleted when the junior doctor processed the job and deletes it from the phone. A record of this is kept on the nurses ward computer and the coordinators tablet PC.

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Example 2- Senior Review Issue

A 35 year old patient with a complex past medical history including alcohol misuse, chronic pancreatitis, asthma and diabetes was on the gastroenterology ward recovering from an ERCP and stent insertion. The patient developed a fever and elevated heart rate, and both his blood pressure and urine output fell profoundly. The ward nurses phoned the H@N co-ordinator at 5.20pm and a F1 (first year) junior doctor arrived at 5.30pm to review the patient. The junior doctor prescribed a 1 litre of 0.9% sodium chloride solution to be given over six hours and took samples for arterial blood gas analysis and blood culture. The F1 told the nursing staff that they would discuss the case with the medical registrar in due course.

At the 10pm handover the patient was discussed with the medical registrar: they immediately attended the ward to find the patient was critically ill, and arranged an urgent transfer to a level three (intensive care) bed. Although the patient survived, they required two weeks on the intensive care unit including periods of ventilation and renal replacement therapy. This may have been avoided if initial management had been more aggressive.

Potential with the New System

The ward nurse is triggered by her concern and the patient's high early warning score to log an urgent (red) task on the ward computer. She is prompted by a pop up box on the screen to additionally speak directly to the coordinator. This task is sent electronically to the coordinator and then allocated by the coordinator to a junior doctor. As the job is marked red it is also automatically copied directly to the medical registrar's mobile phone along with the contact number of the junior doctor the job has been allocated to. The medical registrar is then aware of the patients name, diagnosis, and observations, and knows which junior doctor to discuss the case with. Consequently the medical registrar has oversight of all urgent problems occurring over a wide geographical area. He or she can speak directly to the junior doctor reviewing a patient over the wireless network via their phones to ensure an appropriate management plan is instituted promptly and decide when to review the patient themselves.

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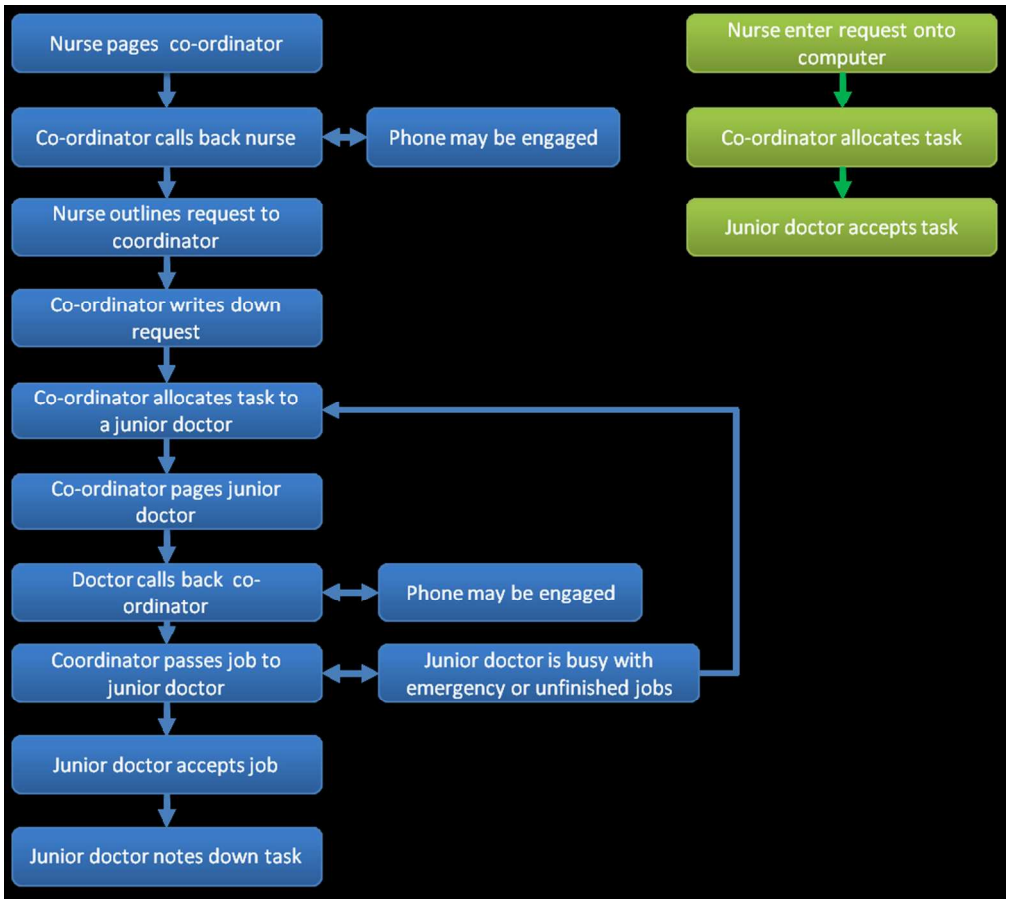

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We thank the reviewers for their comments, and the editorial team for their guidance on reformatting our submission following its transfer to BMJ Open. We have made a number of alterations to our submission in response to these comments and hope the manuscript is now suitable for publication. A revised submission with tracked changes has been uploaded alongside the new version.

Changes Following Editorial Directions

1) We have changed the title of the submission to indicate the type of study
2) An article summary is now included preceding the abstract
3) A data sharing statement has been added at the end of the manuscript

Response to Comments from the Editor of BMJ Quality and Safety

We thank the editor for their assessment of our work as "interesting" and acknowledge the "appropriate audience for your work seems to be a more clinical, general medical journal". We feel the statement that the "benefit is purely the practical message for clinicians in the UK" is a rather limited appraisal of a system with major potential benefits for any geographically dispersed team working with complex problems, especially as we have been invited to present preliminary results relating to this work at a European Union event and joint UK-Norwegian Royal Society of Medicine event. We hope that our revised manuscript better conveys the innovation and broader potential inherent in the system.

Response to Reviewer 1:

We thank the reviewer for noting the study is interesting and well-written.

Major 1: We acknowledge this paper is "specific to UK and Europe"(sic) in its particular focus, but the challenge of staffing hospitals out of hours is a global issue. We have made changes both attempt to further clarify the Hospital at Night System and to emphasise the generalizability of the approach. We also seek to clarify the role of the co-ordinator further to emphasize this is a national directive rather than a local choice.

Major 2: We agree that incidents are under-reported and as the reviewer notes we do clearly say we are not inferring causality in the discussion. We have made alterations to emphasize this limitation and to highlight our emphasis is that the new system is non-inferior in this regard. We do not agree that our results section is misleading as it clearly presents the numbers of incidents that were reported and our supplementary flow diagrams present the distribution of type of incident in great detail.

Major 3: We agree with the reviewer that we did not systematically and directly record nurse or physician actions prior to the implementation of the system so no unbiased comparisons could be

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presented. This is a limitation of the study and we acknowledge this explicitly in the revised discussion section.

Minor 1: A typographical error in reference 4 has been corrected. We apologise for the formatting errors introduced through our use of EndNote which we have now addressed.

Minor 2: The reviewer asks for a discussion of other papers considering wireless working. We have introduced reference to these e-mail based adjuncts but emphasize that the system presented replaces and augments current practice rather than supports it.

Minor 3: We have added a sentence to declare the aspects of the Cisco network that we took advantage of. We feel the use of phones and tablet PCs is clear in the introduction but have clarified our discussion statement with respect to their carriage.

Response to Reviewer 2:

We are grateful for the reviewer's comments which "commend" our attempt to address a "fundamental communication problem that has dire human and financial consequences".

The reviewer raises the issue of the wider applicability of the solution. We have added to the discussion to highlight the potential of the solution and, as noted earlier, made greater reference to the international applicability of the approach.

The reviewer also raises the possibility of the risk of bias as the research involves businesses. The only author who is employed in IT is Dr Wilson who works for a subsidiary of Cisco: we freely acknowledge this and reiterate that Cisco itself had no role in the design or undertaking of the study and that Dr Wilson is their only employee who approved the manuscript. We did not feel that any pressure from the company would be brought to bear on Dr Wilson as the Cisco network we use is present in the great majority of NHS Trusts already and is not the subject of the research. We reiterate that no author has any financial stake in, nor has received any financial incentives, payments, or travel expenses from NerveCentre software. Our involvement with this company has purely been to highlight the clinical need to the developer and to feed back to that team to improve the interfaces used and transparency of the tracking data obtained.

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Multi-modal Observational Assessment of Quality and Productivity Benefits From The~~A Collaborative~~ Implementation of Wireless Technology For Out of Hours Working~~Delivers Significant Benefits in Quality and Productivity from a Multidisciplinary Out of Hours Team~~

John D Blakey[1]

Debbie Guy[2]

Carl Simpson[2]

Andrew Fearn[2]

Sharon Cannaby[3]

Petra Wilson[4]

Dominick E Shaw[1]

[1]Respiratory Biomedical Research Unit, University of Nottingham, Nottingham, UK

[2]City Hospital Campus of Nottingham NHS University Hospitals NHS Trust, Nottingham, NG5 1PB, UK

[3]Head of Health Sector Policy, Association of Chartered Certified Accountants, 29 Lincoln's Inn Fields, London, WC2A 3EE, UK.

[4]European Health and Care Team, Internet Business Solutions Group, Cisco Systems, Brussels, Belgium.

Corresponding author:

Dr Dominick Shaw

Dominic.shaw@nottingham.ac.uk

Respiratory Biomedical Research Unit, Clinical Sciences Building, City Hospital Campus, Nottingham, NG5 1PB.

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Tel: 0115 8231709

Fax: 0115 8231946

Five MesH Keywords: "technology, wireless", "after hours care", "job satisfaction", "length of stay", "risk management"

Word Count: 3931~~3582~~

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SUMMARY

Article Focus

Can an out of hours wireless task requesting and tracking system improve quality and safety in secondary care?

Key Message

The widely adopted Hospital at Night system for out of hours working is inefficient and risks introducing error. We introduced a wireless task requesting and tracking system and showed this change was acceptable, and improved qualitative and quantitative markers of efficiency and safety.

Strengths and Limitations

The study showed clinically meaningful and statistically significant positive changes using a variety of complementary assessments. The study was observational and within a single acute NHS Trust.

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ABSTRACT

Background

Providing out of hours care in hospital is challenging as staff are few and often geographically dispersed~~following the introduction of the Hospital at Night system and the European Working Time Directive~~. Most NHS hospitals rely on ~~a~~ a landline phone and pager system with a co-ordinator~~to~~ matching ~~the correct~~ tasks ~~is performed by t~~ to ~~the correct~~ healthcare professionals. However, this system is inefficient and may contribute to untoward incidents. We investigated if a wireless system of call handling and task management for out of hours care could replace the pager system and improve efficiency, patient safety, and staff satisfaction.

Methods

We used quantitative and qualitative methods, including interviews with staff, a standard satisfaction questionnaire, independent observation, data extraction from work logs and incident reporting systems, and analysis of hospital committee reports to compare the different task handling systems in secondary care in Nottingham.

Results

Users were more satisfied with the new system (satisfaction score 62/90 vs. 82/90, p=0.0080). With the new system over 70 hours per week of co-ordinator time was released, and there were fewer untoward incidents related to handover and medical response (OR=0.30, p=0.02). Broad clinical measures (cardiac arrest calls for peri-arrest situations and length of hospital stay) improved significantly in the areas covered by the new system.

Conclusion

The introduction of call handling software and mobile technology over a medical grade wireless network improved staff satisfaction with the Hospital at Night system. Improvements in efficiency and information flow have been accompanied by a reduction in untoward incidents, length of stay, and peri-arrest calls

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BACKGROUND

Care for patients in hospitals ~~within the NHS~~ is broadly divided into "in hours" which comprises Monday to Friday between 9am and 5pm, and "out of hours" (OOH) which comprises the remainder of the week and public holidays. Patients are therefore subject to out of hours care for three quarters of the year. Out of hours care in the NHS and many other systems is normally provided by junior staff with seniors supporting from home on request. Over the past decade, there has been both a reduction in junior doctors' working hours and an increase in the amount of clinical work both generally[1] and out of hours[2]. Locally in Nottingham, we have seen yearly admissions rise by almost 25000 (15%) between 1999-2000 and 2010-11[3] whilst individual junior doctor's hours have fallen by more than 35% to comply with the European Working Time Directive. As a consequence of this directive, it became apparent that changes to the traditional on-call system were required to maintain patient safety. In response, the Hospital at Night (H@N) project was initiated and adopted nationally[4]. Although the H@N solution is confined to the UK, the issue of maximizing limited clinical resources out of hours is common to almost all secondary healthcare systems and local solutions outside the UK share many of the same features. The issue also arises with non-medical staff, as other healthcare and support professionals such as radiographers or physiotherapists are usually fewer in number and cover a greater area than in normal working hours.

H@N projects intend to achieve safe clinical care using teams comprising junior doctors, nurses and clinical support workers to provide OOH cover. All requests for patient-related tasks from ward nurses are directed through a co-ordinator, usually a senior nurse, who provides a triage function and allocates tasks to team members. This national initiative is intended to deploy a co-ordinated team that ~~allow medical staff more time to engage in clinical activity~~improves efficiency in resource management, particularly allowing medical staff more time to engage in clinical activity. The exact composition of the team varies between hospitals dependent on the composition and volume of the workload and local policy, though all should be risk assessed using standard tools[5]. An initial assessment of the impact of H@N implementation in 2005[4] suggested H@N was as safe as other forms of care. However, subsequent government reports showed both staff numbers and the ratio of staff per bed were higher following implementation of the H@N system [6 7].

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ASSESSMENT OF THE PROBLEM

Nottingham University Hospitals NHS Trust serves 2.5 million people and employs over 13000 staff managing 1700 beds. These beds are divided approximately equally across two sites, Queen's Medical Centre and Nottingham City Hospital (NCH). The H@N service at NCH for out of hours care was introduced in 2006 As with most hospitals, H@N was based around a landline phone and pager system, with requests phoned from the ward to the coordinator and then passed onto the junior doctor or clinical assistant by phone. Two internal reports were conducted after informal concerns were raised over the H@N service[8 9] and their findings are summarised below:

As NCH covers 46.3 hectares and patients enter via eight different specialty admission points, locating the nearest phone was often time-consuming for junior doctors who were in transit across the site. The number they responded to was also often engaged due to the volume of calls. This led to delays in calls being answered, and potential delay in clinical action being taken. The co-ordinator introduced as part of the national H@N initiative spent their shift answering and making phone calls from an office rather than providing senior nursing input. This repetitive role with minimal clinical contact had a negative impact on their morale. These frequent calls also interrupted clinical care provided by doctors and nurses, as they have been shown to do in other settings[10].

It became apparent in Nottingham, as it did nationally, that the H@N service was limited by issues around task allocation and impaired communication between team members[8]. The passing of clinical information from one team to another (handover) is a particular area of concern[11 12~~10 11~~], ~~–~~is something junior doctors feel ill-prepared to do[13~~12~~] and is frequently done rapidly and inaccurately[14 15~~13 14~~].

The H@N system also highlighted issues with transcription of information: Each junior made notes on loose paper when calls were received, and these were sometimes very brief because pressing clinical matters curtailed conversations. Should the paper be lost or damaged, or the information be noted inaccurately, basic details could be difficult and time-consuming to reassemble. At the end of a shift, doctors often took their notes home rather than disposing of them as confidential waste or filing them in patient records, with attendant information governance issues. These issues have also been highlighted as

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sources of error outside the NHS[16]. Verbal handover and hand-written records also led to a difficulty in assessing what actual work was being completed in each shift and by whom, meaning little information was available for workforce planning and feedback to in hours care regarding tasks that should have been completed during that period (e.g. drug card rewrites, warfarin prescribing).

The installation of a Medical-Grade Network (Cisco Systems, San Jose, USA) across the University Hospitals Nottingham NHS Trust sites afforded the opportunity to introduce a secure wireless communications system for H@N. We worked with an industry collaborator (NerveCentre Software, Wokingham, UK) to design and implement a software system to promote efficiency and reduce risk within H@N. The software builds on components from the "borderless" and "collaboration" aspects of the Cisco network and the power and connectivity of the wired components.

All tasks are now logged on to ward-based desktop PCs using the standardised and validated "SBAR" (Situation-Background-Assessment-Recommendation) format [17-19~~15 17~~] recommended by the NHS Institute for Innovation and Improvement (http://www.institute.nhs.uk/). The task is then sent wirelessly to a coordinator who carries a small tablet PC weighing 0.5kg. This task can then be triaged and allocated wirelessly to the most appropriate team member (the co-ordinator included). Tasks are relayed to junior doctors and support workers via a message to dedicated on-call mobile phones (see figure one). The recipient accepts the task with a single button press and it is added to the freely accessible task list held on their phone. Once a task is passed to a junior doctor and accepted it stays active on both their and the co-ordinator's list until completion or reassignment to another individual. The system allows task prioritisation with jobs labelled as green, amber or red depending upon clinical need (see supplementary material). All "red" tasks are copied to a phone carried by the middle grade doctor so they are aware of all potentially serious problems and can attend to assist or review as necessary. Pagers are now only carried by the cardiac arrest team as a fail-safe.

We set out to assess the effect of the implementation of this new system on staff satisfaction, information flow, and broad clinical outcomes.

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METHODS

We drew on the European Commission funded Model for Assessment of Telemedicine[20~~18~~] and the proposals of Westbrook and colleagues[21~~19~~] to inform our study methodology. This paper focuses on staff satisfaction and patient safety outcomes at NCH.

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Review of Untoward Incidents

Two authors (DES and JDB) reviewed all clinical incidents that had been reported in accordance with NHS policy via Datix software (Datix Ltd, London, UK) in the Medical Directorate over two periods of two months preceding (January and February 2011) and subsequent to (June and July 2011) the introduction of the new task allocation system. We chose these two month periods as the total number of reported incidents was identical. We selected the incidents that occurred out of hours and were related to handover of information or job allocation. In the case of disagreement, arbitration was undertaken by a third author. The proportion of calls related to slow response of the H@N service or handover to or within the H@N service were compared by Chi-square test. We acknowledge that incidents are traditionally under-reported in secondary care and as such the aim of this analysis was to ensure the new system did not introduce any major new issues.

The number and directorate location (covered by H@N or not) of cardiac arrest calls placed at Nottingham City Hospital were recorded for a six month period (February to July) in 2010 prior to the introduction of H@N, and for the equivalent period one year later. We recorded an "actual arrest" where CPR or defibrillation or intubation was required as recorded on the Trust's standard cardiac arrest call audit form. "Urgent calls" were those where assistance was required with an unwell patient. Three genuinely false calls requiring no medical intervention were discounted. The numbers of calls per month before and after the new system was introduced were compared by Mann-Whitney test.

Staff Interviews and Observation

To assess the overall impact of the new system on staff satisfaction we undertook observation of, and non-directive interviews with, a purposive sample of H@N co-ordinators, junior doctors using the system, senior doctors, ward nursing staff, and Trust management. A brief and flexible interview framework was agreed to elicit opinion and experiences regarding advantages or problems with the two systems for use out of hours, information handover, and the impact of the changes on the Trust generally. We also asked 20 users (5

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junior doctors, 5 co-ordinators, 5 ward nurses, and 5 clinical support workers) selected in a quasi-random fashion (by day of week on shift) to complete a modified version of the IBM Computer System Usability Questionnaire[2220] before and after the introduction of NerveCentre software and wireless devices. These non-normally distributed paired data were analysed by Wilcoxon signed rank test.

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H@N Co-ordinator Activity

To assess the impact of the new system on the activity of the H@N coordinator, we recorded their activity for one week prior to its introduction (in March 2010), and again for a week one year later. The parameters recorded were: The time spent by H@N co-ordinator on direct clinical care, the number of phone calls made and received, the time spent on logging and distributing tasks, the time spent giving telephone advice, and the number of tasks assigned whilst away from their desk. The change in these parameters with the introduction of NerveCentre was assessed by t-test.

Length of Stay Statistics

We assessed the weekly mean of lengths of stay for six months prior to the introduction of the new system (February to July 2010) and for the same six months in 2011 using centrally collated Trust statistics. The lengths of stay were compared by Mann-Whitney test.

RESULTS

Review of Untoward Incidents

In both two month periods there were 552 electronically reported incidents. Of these, the majority related to patients falls (see supplementary figures three and four for a detailed breakdown). On systematic review of all 1104 incidents, we found 17 to be related to inadequate or absent handover, or to a slow response of H@N, which resulted in actual patient harm or required remedial action to prevent this. 13 of these occurred prior to wireless working and 4 after its introduction. Exposure to wireless working was therefore associated with a reduction in the proportion of incidents that were attributable to the H@N system (OR=0.308, p=0.028 by Chi-square test).

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During the study periods, there was no change in the overall number of cardiac arrest calls placed at the NCH site (median 22.5 per month before and 21 after, p=0.973) though the total number of arrest calls for the Trust as a whole increased significantly (from 57.5 to 72 per month, p=0.041). In the initial six months 26% of cardiac arrest calls placed within the area covered by H@N were to obtain help with patients who had not arrested. This proportion fell significantly to 11% after the new system was implemented (p=0.015).

Interviews

Three main themes repeatedly arose from the interviews and concerned the satisfaction of staff with the old H@N system, concerns over resource management, and concerns over the accuracy of information transcription.

Satisfaction of Staff with Their Role in the H@N system

All grades and professions reported a step change in their satisfaction with the H@N system. This was largely attributable to the facilitation of communication resulting in a marked increase in the time individuals spent undertaking tasks for which they felt they had been trained. The H@N co-ordinators felt this change most acutely, one saying simply:

"*It has given me my job back*" (H@N co-ordinator)

Other co-ordinators were similarly enthused to be released from overwhelming administrative duties:

"*The system required you to be on the computer all the time. I didn't like that. I'm not a computer person; I'm a hands-on clinical person*." (H@N co-ordinator)

Many said that they were considering or actively seeking alternative employment before the new system was implemented:

"*I wouldn't have stayed in this job if thing's hadn't changed. I would have left*." (H@N co-ordinator)

Frustration was not confined to the nursing staff, with middle grade doctors conveying their disenfranchisement with the hospital at night system, sometimes in explicit language not reproduced here.

"*Initially we used to know what was going off* [patients who are ill]*. Hospital at Night put a barrier between the reg* [middle grade] *and the rest of hospital. Having the Blackberry*

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[mobile phone] *does make a difference. I can finally get hold of someone quickly to give advice or to let them know if I've got stuck on labour suite or somewhere."* (Middle grade)

Resource Management

A recurring theme in the old system was that all pages that co-ordinators or junior doctors received appeared equally important until answered, and the process of answering pages from wards was time-consuming. A co-ordinator explained she was often receiving pages faster than they could be answered, without knowing which to call back as a priority:

"(we) would write down the phone numbers and work through them one by one. For each number we would call the ward, and then bleep [page] *the doctor .... which could take ten minutes if the doctor was not near a phone or was busy."* (H@N co-ordinator)

It was also only by paging doctors or support workers that the co-ordinator could assess if they had completed their tasks, risking introducing additional delays.

"We had no idea when a doctor had completed a task or how long they are with a particular patient. If we page them we often take them away from the patient." (H@N co-ordinator)

A ward sister commented that nurses placing bleeps grew frustrated with delays in obtaining a response and spent valuable time ~~recontacting~~re-contacting the co-ordinator to ensure the task was treated ~~approapriately~~appropriately:

"the efficiency of the new system, with nurses not needing to chase doctors, means nursing staff can spend more time with patients" (ward nurse)

Junior doctors were impressed at the reduction in time and inconvenience as the need to be bleeped greatly diminished. They also were relieved that their workload could be accurately monitored, improving the coordinators ability to distribute work evenly.

"I can easily contact the H@N co-ordinator, and she can see my outstanding workload at any time. It has taken away the worry that I'm leaving patients waiting." (Junior doctor)

Senior doctors also had grown concerned with their inability to assess what actual work was being done by their juniors. Their perspective tended to be concern over potential medico-legal issues..

*"Tasks range from the simple, rewriting a drug card, to the complicated, organizing a brain scan for a critically unwell unconscious adult at 4am....Our system did not accurately capture the breadth and depth of the complexities involved." (*Medical consultant*)*

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The Transcription of Information

A major issue with the previous hospital at night system was the concern over the repeated verbal transfer of limited information. There was enthusiasm for the change in practice the new system has facilitated:

*"It's great how the new system categorizes everything. It forces you to provide all the necessary information so that the doctor is properly prepared and turns up at the right place at the right time with the right patient details" (*Ward sister*)*

Junior doctors expressed additional concerns over their own transcription of patient details when paged whilst busy, and their fear of losing their job list:

*"I must have noted down the wrong name so I couldn't find the patient. I kept phoning the hospital at night co-ordinator but the phone was engaged so I just handed the job back at the end of the shift." (*Junior doctor*)"Love the fact that I don't need to carry paper around. There is no risk anymore that I'll lose my patient list" (*Junior doctor*)*

As the H@N team is staffed by individuals in training posts, they are required to log the cases they see and the procedures they undertake. Few, if any, had time to prepare an anonymised second list to complement their job sheet. As a list of tasks they completed can now be emailed to each doctor at the end of the shift, this pressure has been removed.

*"It was incredibly difficult to document the experience gained at night" (*Junior Doctor*)*

Other comments that were repeated concerned the benefits in terms of reduced noise on the wards given the reduced need to make and receive phone calls, and the great potential the project had for monitoring and planning out of hours care in the future.

Satisfaction survey

Staff satisfaction with the H@N system itself improved significantly (p=0.008, Wilcoxon signed rank test) from a median score of 62 (maximum possible = 90) with the pager-based system to a median of 82 with the NerveCentre wireless technology system (see table one). The minimum response score for each category improved markedly such that no-one recorded less than 8 out of ten for their overall satisfaction with the system.

H@N Coordinator Activity

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Over the periods studied, the total number of tasks per shift assigned by the H@N co-ordinator did not differ significantly (weekly total 1280 vs. 1379, comparison by tasks allocated per shift p=0.695). However, the number of tasks assigned to a team member whilst the co-ordinator was at their desk dropped sharply (weekly total 1280 vs. 99, $p<10^{-36}$). The time spent receiving and logging calls during each shift also fell markedly (see figure two) from a median (IQR) of 97% (4.32) of total shift time to 42% (27.47) of shift time ($p<10^{-36}$). Commensurate to the decrease in time spent on the telephone and the ability to assign tasks away from their desks, co-ordinators were able to begin to engage in clinical care. Direct clinical care time increase from a baseline of zero to a median (IQR) of 56% (28.14) of shift time.

Length of Stay Statistics

The median length of stay on medical wards covered by NCH H@N was 6.50 days (n=839 in-patient stays) in the study period in 2010 and 5.67 days (n=739) in 2011 (P=0.004 by Mann-Whitney test). The median length of stay on other wards which were neither day-case units nor covered by NCH H@N was 2.90 days (n=1279 in-patient stays) in the study period in 2010 and 2.67 days (n=1254) in 2011 (P=0.263).

DISCUSSION

In this study, we describe the implementation of a wireless system that allows task request, allocation, and management on handheld devices for out of hours care. Our evaluation of the new hardware and software reviewed aspects of patient safety, utilisation of resources, and staff satisfaction by comparing operational processes before and after implementation.

The implementation of wireless working was extremely well received by all users with particular praise for the improvements in task-flow efficiency and information governance achieved. The H@N co-ordinators reported feeling liberated by the system and are spending vastly greater time engaged in direct clinical activity. A further marker of this is that long-standing vacancies for co-ordinator posts have now been filled. Although causality cannot be inferred, broad clinical measures such as length of stay and cardiac arrest calls placed for unwell patients fell significantly with the change in H@N system supporting at least clinical non-inferiority of new method.

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Wireless systems similar to the one described here are not yet commonplace in secondary care in Europe~~the UK~~, although~~but~~ limited computerized handover systems have shown the potential for patient benefit[23 24~~21 22~~]. Early adopters in other countries have seen improvements in clinical outcomes not only using a network to manage information passing within clinical teams, but also to track over pieces of equipment using radio-frequency identification tags[25 26~~23 24~~] and with electronic nursing records[27~~25~~]. Limited data on the use of push e-mail to support current practise also exists[28]. However, these initiatives tend to be adjuncts rather than replacements for current systems, and they are usually generic rather than tailored for purpose so do not include a standard data entry format with automatic population of fields and drop-down menus, and they do not automatically grade the urgency of communications.

Wireless technology also has the potential to allow advanced patient monitoring which can improve patient outcomes[29 30] and save money[31]. We see also potential for this system to collect data which will highlight wards where routine tasks are not completed in hours, to monitor the performance of different composition of out of hours teams of junior doctors, and to add clinical parameters to a dashboard of Trust performance. As the mobile devices are able to record the location of the users indoors and out, there is also scope for time and motion study to further increase efficiency. The wider applicability of an approach such as this to any group of individuals addressing complex and dynamic tasks with limited and geographically dispersed resources has also become apparent. Locally, portering and critical care outreach services have adopted a similar system for in-hours working, and it is being revised to manage personnel staffing emergency theatre lists and their liaison with ward nurses.

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There is clearly a difficulty in assessing the impact of complex service delivery interventions such as the one described. It is practically extremely challenging to undertake a randomised trial of the system described as few centres have an appropriate network and it would require a considerable investment in equipment and staff training. Furthermore, one major

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flaw in the traditional pager system is its inability to accurately record activity. It is therefore difficult to assess the impact of the system at a ward or patient level as detailed information is only available post-introduction. We also acknowledge that we did not systematically record nurse and physician activity before and after implementation in the same way as was undertaken for the co-ordinators. Although the introduction of the new wireless working was associated with improvement in broad clinical measures we also emphasize~~accept~~ that this single centre observational study cannot prove causality. Future studies are needed to assess any benefits on patient safety or length of stay.

A major barrier to the implementation of this potentially highly productive system is cost, a factor influential in the design of H@N services nationally[32,~~29~~]. The total cost of the software purchase and deployment across both Trust sites, and the additional hardware required for the project (40 phones for junior doctors and clinical support workers and 4 tablet computers for co-ordinators) was less than~~approximately~~ £150000. However, early indications are these costs will be offset relatively rapidly by the improved workforce planning facilitated by the system, by the reduction in delayed discharges or procedures, and through fewer untoward incidents.

Wireless technology and securely held electronic data have become a central part of daily life outside the NHS. In this paper we present an acceptable way of introducing such technology to address some of the issues common to Hospital at Night systems: we found it to be welcomed by users, efficient, and be correlated with improved broad clinical outcomes.

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TABLES

Table 1 – Comparative satisfaction of users of the old and new H@N systems. Scores are median values for 20 staff members (5 junior doctors, 5 H@N co-ordinators, 5 clinical support workers, and 5 ward nurses) for a modified version of the IBM Computer System Usability Questionnaire[22~~20~~].

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Statement	Old System		New System	
	Median	Minimum	Median	Minimum
Overall I am satisfied with how easy it is to use the system	7	1	9	7
It was easy to learn to use the system	9	1	10	5
The system takes little of my time allowing me to spend more time with patients	6	1	10	7
The system allows information on the patient to be accurately recorded	5	0	10	7
I feel comfortable using the system	8	1	10	7
Whenever I make a mistake using the system I recover quickly and without impact to safety	8	1	9	7
The organisation of information on the screens is clear	6	1	9	7
I like using the interface on this system	6	0	9	5
Overall, I am satisfied that the system effectively supports my job	7	0	9	8
TOTAL SCORE n	62		85	

FIGURE LEGENDS

Figure One: Flow of Information for One Request Under The Two H@N Systems

Figure Two: Box plot showing the percentage of H@N co-ordinator time spent logging and allocating tasks across shifts in comparable weeks in March 2010 and 2011, before and after the introduction of NerveCentre and wireless technology.

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COMPETING INTERESTS

PW is employed by the manufacturer of the medical grade network used in this study (Cisco Systems). The other authors have no conflict of interest to declare. The commercial entities Cisco Systems and NerveCentre Software had no role in the design and execution of analyses, and were not permitted access to patient identifiable data.

AUTHOR CONTRIBUTIONS

DES, SC, PW, AF, and JDB conceived of the ideas for study. DES, AF, and JDB designed the study. DG, SC, and PW undertook non-directive interviews and administered the questionnaires. CS collected and compiled data on cardiac arrest calls. AF and JDB acquired the clinical data. JDB, DES, and DG reviewed the incident reports. JDB undertook the analyses. JDB and DES drafted the manuscript which all authors approved.

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DATA SHARING

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Supplementary data is available as indicated in the body of the manuscript.

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REFERENCES

1. Peacock PJ, Peacock JL, Victor CR, Chazot C. Changes in the emergency workload of the London Ambulance Service between 1989 and 1999. *Emerg Med J* 2005;22(1):56-9.
2. Thompson C, Hayhurst C, Boyle A. How have changes to out-of-hours primary care services since 2004 affected emergency department attendances at a UK District General Hospital? A longitudinal study. *Emerg Med J* 2010;27(1):22-5.
3. HESOnline: Hospital Episode Statistics. *NHS Health and Social Care Information Centre*, 2011.
4. Mahon A, Harris C, Tyrer J, Carr S, Lowson K, Carr L, et al. The implementation and impact of Hospital at Night projects. In: Department of Health, editor. London: Crown, 2005.
5. NPSA. Hospital at Night - Patient Safety Risk Assessment Guide. Department of Health, , 2005.
6. NHS Workforce Projects. Model Hospital at Night Team: 2007 Survey Findings.: Department of Health, 2008.
7. NHS Workforce Projects. The Case for Hospital at Night - The Search for Evidence. Department of Health, 2011.
8. Teahon K. Report on a Study of May 2009. *Medical Out of Hours Service City Campus* University Hosptials Nottingham NHS Trust, 2009.
9. Wallace S, McKinnin S, Guy D. External Review of Hospital at Night. *Medical Out of Hours Service City Campus*: University Hosptials Nottingham NHS Trust, 2010.
10. Katz MH, Schroeder SA. The sounds of the hospital. Paging patterns in three teaching hospitals. *N Engl J Med* 1988;319(24):1585-9.
11. Bywaters E, Calvert S, Eccles S, Eunson G, Macklin D, McCullough C, et al. Safe Handover: Safe Patients: British Medical Association, 2004.
12. Rabol LI, Andersen ML, Ostergaard D, Bjorn B, Lilja B, Mogensen T. Descriptions of verbal communication errors between staff. An analysis of 84 root cause analysis-reports from Danish hospitals. *BMJ Qual Saf* 2011;20(3):268-74.
13. Cleland JA, Ross S, Miller SC, Patey R. "There is a chain of Chinese whispers ...": empirical data support the call to formally teach handover to prequalification doctors. *Qual Saf Health Care* 2009;18(4):267-71.
14. Tokode M, O'Riordan B, Barthelmes L. "That's all I got handed over": missed opportunities and opportunity for near misses in Wales. *Bmj* 2006;332(7541):610.
15. Sithamparanathan M. Personal views - "That's all I got handed over". *Brit Med J* 2006;332(7539):496-96.
16. Volpp KG, Grande D. Residents' suggestions for reducing errors in teaching hospitals. *N Engl J Med* 2003;348(9):851-5.
17. Haig KM, Sutton S, Whittington J. SBAR: a shared mental model for improving communication between clinicians. *Jt Comm J Qual Patient Saf* 2006;32(3):167-75.
18. Hohenhaus S, Powell S, Hohenhaus J. Enhancing Patient Safety During Hand-Offs: Standardized communication and teamwork using the 'SBAR' method. *American Journal of Nursing* 2006;106(8):72A-72B.
19. Beckett CD, Kipnis G. Collaborative communication: integrating SBAR to improve quality/patient safety outcomes. *J Healthc Qual* 2009;31(5):19-28.
20. Kidholm K, Bowes A, Dyrehauge S, Ekeland AG, Flottorp SA, Jensen LK, et al. The MAST Manual: Model for Assessment of Telemedicine, 2010.
21. Westbrook JI, Braithwaite J, Iedema R, Coieraa RW. Evaluating the impact of information communication technologies on complex organizational systems: a multi-disciplinary, multi-method framework. In: Fieschi M, editor. *Studies in Health Technology and Informatics*. Amsterdam: IOS Press, 2004:1323-27.

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For peer review only

22. Lewis JR. Ibm Computer Usability Satisfaction Questionnaires - Psychometric Evaluation and Instructions for Use. *Int J Hum-Comput Int* 1995;7(1):57-78.
23. Raptis DA, Fernandes C, Chua W, Boulos PB. Electronic software significantly improves quality of handover in a London teaching hospital. *Health Informatics J* 2009;15(3):191-8.
24. Ryan S, O'Riordan JM, Tierney S, Conlon KC, Ridgway PF. Impact of a new electronic handover system in surgery. *Int J Surg* 2011;9(3):217-20.
25. HIAE. Hospital Israelita Albert Einstein Protocols. Sao Paolo, 2011.
26. Cisco-Systems. Brazilian Hospital Deploys Innovative Services. *MGN Consumer Case Studies*, 2011.
27. Lindgren CL, Elie LG, Vidal EC, Vasserman A. Transforming to a Computerized System for Nursing Care Organizational Success Within Magnet Idealism. *Cin-Comput Inform Nu* 2010;28(2):74-78.
28. O'Connor C, Friedrich JO, Scales DC, Adhikari NK. The use of wireless e-mail to improve healthcare team communication. *J Am Med Inform Assoc* 2009;16(5):705-13.
29. Abraham WT, Adamson PB, Bourge RC, Aaron MF, Costanzo MR, Stevenson LW, et al. Wireless pulmonary artery haemodynamic monitoring in chronic heart failure: a randomised controlled trial. *Lancet* 2011;377(9766):658-66.
30. Lilly CM, Cody S, Zhao H, Landry K, Baker SP, McIlwaine J, et al. Hospital mortality, length of stay, and preventable complications among critically ill patients before and after tele-ICU reengineering of critical care processes. *JAMA* 2011;305(21):2175-83.
31. Leong JR, Sirio CA, Rotondi AJ. eICU program favorably affects clinical and economic outcomes. *Crit Care* 2005;9(5):E22.
32. Hospital at Night Baseline Report: NHS, 2006.

1. Peacock PJ, Peacock JL, Victor CR, Chazot C. Changes in the emergency workload of the London Ambulance Service between 1989 and 1999. *Emerg Med J* 2005;22(1):56-9.
2. Thompson C, Hayhurst C, Boyle A. How have changes to out-of-hours primary care services since 2004 affected emergency department attendances at a UK District General Hospital? A longitudinal study. *Emerg Med J* 2010;27(1):22-5.
3. HESOnline: Hospital Episode Statistics. *NHS Health and Social Care Information Centre*, 2011.
4. Mahon A, Harris C, Tyrer J, Carr S, Lowson K, Carr L, et al. The implementation and impact of Hosptial at Night projects. In: Health Do, editor, 2005.
5. NPSA. Hospital at Night - Patient Safety Risk Assessment Guide. In: Health Do, editor, 2005.
6. NHS_Workforce_Projects. Model Hospital at Night Team: 2007 Survey Findings. In: Health Do, editor, 2008.
7. NHS_Workforce_Projects. The Case for Hospital at Night - The Search for Evidence. In: Health Df, editor, 2011.
8. Teahon K. Report on a Study of May 2009. *Medical Out of Hours Service City Campus* University Hosptials Nottingham NHS Trust, 2009.
9. Wallace S, McKinnin S, Guy D. External Review of Hospital at Night. *Medical Out of Hours Service City Campus*: University Hosptials Nottingham NHS Trust, 2010.
10. Bywaters E, Calvert S, Eccles S, Eunson G, Macklin D, McCullough C, et al. Safe Handover: Safe Patients: British Medical Association, 2004.
11. Rabol LI, Andersen ML, Ostergaard D, Bjorn B, Lilja B, Mogensen T. Descriptions of verbal communication errors between staff. An analysis of 84 root cause analysis-reports from Danish hospitals. *BMJ Qual Saf* 2011;20(3):268-74.
12. Cleland JA, Ross S, Miller SC, Patey R. "There is a chain of Chinese whispers ...": empirical data support the call to formally teach handover to prequalification doctors. *Qual Saf Health Care* 2009;18(4):267-71.

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For peer review only

13. Tokode M, O'Riordan B, Barthelmes L. "That's all I got handed over": missed opportunities and opportunity for near misses in Wales. *Bmj* 2006;332(7541):610.
14. Sithamparanathan M. Personal views "That's all I got handed over". *Brit Med J* 2006;332(7539):496-96.
15. Haig KM, Sutton S, Whittington J. SBAR: a shared mental model for improving communication between clinicians. *Jt Comm J Qual Patient Saf* 2006;32(3):167-75.
16. Hohenhaus S, Powell S, Hohenhaus J. Enhancing Patient Safety During Hand-Offs: Standardized communication and teamwork using the 'SBAR' method. *American Journal of Nursing* 2006;106(8):72A-72B.
17. Beckett CD, Kipnis G. Collaborative communication: integrating SBAR to improve quality/patient safety outcomes. *J Healthc Qual* 2009;31(5):19-28.
18. Kidholm K, Bowes A, Dyrehauge S, Ekeland AG, Flottorp SA, Jensen LK, et al. The MAST Manual: Model for Assessment of Telemedicine, 2010.
19. Westbrook JI, Braithwaite J, Iedema R, Coiera RW. Evaluating the impact of information communication technologies on complex organizational systems: a multi-disciplinary, multi-method framework. In: Fieschi M, editor. *Studies in Health Technology and Informatics*. Amsterdam: IOS Press, 2004:1323-27.
20. Lewis JR. Ibm Computer Usability Satisfaction Questionnaires Psychometric Evaluation and Instructions for Use. *Int J Hum-Comput Int* 1995;7(1):57-78.
21. Raptis DA, Fernandes C, Chua W, Boulos PB. Electronic software significantly improves quality of handover in a London teaching hospital. *Health Informatics J* 2009;15(3):191-8.
22. Ryan S, O'Riordan JM, Tierney S, Conlon KC, Ridgway PF. Impact of a new electronic handover system in surgery. *Int J Surg* 2011;9(3):217-20.
23. HIAE. Hospital Israelita Albert Einstein Protocols. Sao Paolo, 2011.
24. Cisco Systems. Brazilian Hospital Deploys Innovative Services. *MGN Consumer Case Studies*, 2011.
25. Lindgren CL, Elie LG, Vidal EC, Vasserman A. Transforming to a Computerized System for Nursing Care Organizational Success Within Magnet Idealism. *Cin-Comput Inform Nu* 2010;28(2):74-78.
26. Abraham WT, Adamson PB, Bourge RC, Aaron MF, Costanzo MR, Stevenson LW, et al. Wireless pulmonary artery haemodynamic monitoring in chronic heart failure: a randomised controlled trial. *Lancet* 2011;377(9766):658-66.
27. Lilly CM, Cody S, Zhao H, Landry K, Baker SP, McIlwaine J, et al. Hospital mortality, length of stay, and preventable complications among critically ill patients before and after tele-ICU reengineering of critical care processes. *JAMA* 2011;305(21):2175-83.
28. Leong JR, Sirio CA, Rotondi AJ. eICU program favorably affects clinical and economic outcomes. *Crit Care* 2005;9(5):E22.
29. Hospital at Night Baseline Report: NHS, 2006.

For peer review only