

## MAIN TEXT

### SINGLE ROOM WARD DESIGN AND ITS IMPACT ON SERVICE AND PATIENT OUTCOMES: AN EVALUATION STUDY

#### INTRODUCTION

More than 100 years ago Florence Nightingale argued that health professionals needed to use a structured care environment to support patient wellbeing and recovery (Wayne, 2014).

Traditionally, hospitals were designed as dormitory style open rooms and more recently multiple occupation open-bay rooms. Subsequently, each in-patient ward was designed to accommodate specific patient groups according to conditions and or injuries, such as orthopaedic trauma. As a result globally public hospital inpatient wards were designed for multiple occupancy using open-bay rooms containing four-six beds.

There is emerging evidence that patients accommodated in open-bay rooms are at higher risk of nosocomial infections; adverse events; and breaches in their privacy (Allegranzi, 2011;

Bloemendaal et al., 2009; Bonizzoli et al., 2011; Cheng et al., 2010; Lenhart, Stickler, Kriz, Angerler, & Tucek, 2008; Meredith, Jnah, & Newberry, 2017; Meyer, Schwab, & Gastmeier, 2010; Roberts et al., 2011; Skally et al., 2009). In response to this increasing evidence,

organisations are prioritising single room design inpatient wards in preference to traditional open-bay wards when building new/redeveloping patient accommodation (Sadatsafavi, Niknejad, Shepley, & Sadatsafavi, 2017; Sadatsafavi, Niknejad, Zadeh, & Sadatsafavi, 2016).

Despite the evidence that open-bay room wards increase patient risk, there is scant evidence that single room wards reduce risk or improve outcomes. Specifically, there is limited evidence demonstrating the impact of a single room ward design on infection rates, patient satisfaction, clinician experiences, work flow and adverse events (Chaudhury, Mahmood, & Valente, 2006; National Health Service, 2008; Sadatsafavi et al., 2017; Sadatsafavi et al., 2016; van de Glind, de Roode, & Goossensen, 2007).

The risk of nosocomial infection can lead to devastating adverse outcomes. Patients with orthopaedic injuries are particularly vulnerable to infection (Cunningham, Kavolus, Bolognesi, Wellman, & Seyler, 2017; United States Bone and Joint Initiative, 2014). One of the most common organisms identified in osteomyelitis is *Methicillin Resistant Staphylococcus Aureus* (MRSA) (Flynn, Kellagher, & Simpson, 2010; Lewis, Miller, & Davies, 2004). Therefore, strategies that minimize cross-infection for orthopaedic patients are critical as they are vulnerable to infection (Finkelstein et al., 2017; United States Bone and Joint Initiative, 2014).

Traditionally, orthopaedic patients are also at risk of other adverse events such as falls (Cunningham et al., 2017; Flynn et al., 2010). A study in North America examined the falls in one adult orthopaedic ward and found that 21.8% of falls resulted in patient injuries with 4.8% of injuries were classified as a serious adverse event (Mandl et al., 2013). Minimising adverse events such as falls and nosocomial infections is paramount to patient recovery and well-being (United States Bone and Joint Initiative, 2014). Orthopaedic nurses play a pivotal role in preventing adverse events (Chu, 2017; Mandl et al., 2013). Nursing strategies for reducing adverse events have focused primarily on direct patient care and observation. However, to date there is little evidence about how single rooms impact on adverse events when compared to open-bay wards.

There is some evidence to suggest that patient satisfaction improves when care is delivered in single rooms (Janssen, Klein, Harris, Soolsma, & Seymour, 2000; Lawson & Phiri, 2000). For example, a study conducted in the United Kingdom, explored patient satisfaction with care in both single and open-bay rooms. Self-reported satisfaction was higher for patients cared for in a single room (Lawson & Phiri, 2000). As a consequence, single rooms are the predominant inpatient ward contemporary design currently adopted by many governments and private health care organisations.

Despite the overwhelming predominance and construction of new single room inpatient ward facilities evidence remains limited that this design improves patient satisfaction, reduces

adverse events and or adds value for health professionals' satisfaction and flow. Therefore, the aim of this study was to evaluate the impact of a new inpatient single room orthopaedic ward on patient outcomes and satisfaction and health professionals' perceptions of patient safety and satisfaction.

## **METHODS**

Multiple methods were used to evaluate the impact of a newly designed inpatient single room orthopaedic ward on patient outcomes and patients' and health professionals' perceptions. The multiple methods included: a medical record audit; patient, nursing and medical staff surveys; and non-participant observations.

### **Setting**

This was a single site study, which was conducted in one major tertiary referral hospital within metropolitan Sydney, Australia. A new hospital building containing a 28 single room orthopaedic inpatient ward was built and patients, health professionals and equipment were moved into the new single room ward. From this point forward, orthopaedic patients were managed in single rooms rather than the traditional four-bedded open-bay rooms. There were 39 permanently employed nurses comprising registered, enrolled (licensed practical) and assistant (certified nursing assistant) nurses. The workforce size was the same in both study phases. 24 orthopaedic staff specialist (board certified) doctors provided care to the patients. The nurse to patient ratio was the same before and after the move i.e. 4 to 5:1 during the day and 9:1 at night.

### **Medical record audit**

A before and after retrospective medical record audit was conducted to compare patient outcomes for care and treatment delivered in single room and open-bay room wards. Data were obtained for the six months before the move. Then three months after the move another six months of data were obtained. Inclusion criteria included: all patients treated in the orthopaedic wards during the study period. Data collection included: patient demographics (age and gender),

adverse events (e.g. MRSA rates, falls, bedside emergency call activation), diagnosis, disposition and length of stay. Patient data were obtained from the hospital Incident Information Management System (IIMS), electronic medical records (EMR) and paper based medical records held by the infection control department. There were no exclusion criteria.

### **Nurses' survey**

A paper based anonymous nurse survey was developed using expert opinion and findings from relevant published studies. Three nurses assessed the content validity. The 20-item nurse survey included demographic and professional characteristics and was designed to elicit nurses' perceptions of the single room compared to the open-bay ward environment and the impact on workload, satisfaction and patients' recovery. A purposive sample of nurses was invited to participate to explore their perceptions of managing patients both in the single room and open-bay wards. The survey was available to nurses in common areas over a six month period. Completed surveys were returned via sealed boxes located within common areas. Nurses who were permanently employed in the new ward for greater than six months were invited to participate.

### **Medical doctors' survey**

A survey designed to examine medical doctors' views of the single room design ward was developed using expert opinion and findings from relevant published studies. The 14-item survey included demographic and professional characteristics and was designed to elicit medical doctors' perceptions of the effect of single room compared to the open-bay ward environment on patient outcomes and recovery. A purposive sample of medical doctors was invited to participate to explore their perceptions of managing patients both in a single room and open-bay ward. This anonymous and paper based survey was administered over a six month period. Surveys were made available in all clinical and common areas and could be returned via sealed

boxes located within common areas. All medical doctors working in the orthopaedic department during the study period were invited to participate.

### **Patients' survey**

An anonymous inpatient survey was developed using expert opinion and findings from relevant published studies. The 17-item survey was piloted by five patients who assessed the content validity. The survey items were designed to elicit patients' perceptions of the single room and open-bay ward design, nursing care, satisfaction, sleep patterns and timeliness of care. Patient inclusion criteria included: all patients treated in the ward during the study period, able to read and understand English and with sufficient cognitive acumen to complete the survey independently. Patients were provided the survey as part of the admission information package and returned the survey to a sealed box located in a prominent position in the ward.

### **Non-participant observation**

Non-participant observations (20-30 hours or until data saturation) were undertaken by the lead researcher in the single room ward. This enabled observation of nurses' activities and care practices in the single room ward and was non-participatory. A convenience sample of orthopaedic nurses was invited to be observed. All permanently employed registered nurses, who had been employed in this ward for >12 months were invited to participate in the study. Signage about the study was posted around the ward and researchers explained their presence at the beginning of each shift and obtained informed consent from those who agreed to undergo one to one direct observation. Notes about the activities for the remainder of clinicians who declined to be observed were not taken.

Non-participant observations were focused on nursing practices and work flow while caring for patients in the single rooms. The lead investigator observed nurses working during morning, evening and night shifts over a two month period. Using field notes the observer collected data on nursing practice, communication processes and clinician interactions.

## **Ethical considerations**

Ethical approval was provided by the local Human Research Ethics Committee (LNR/LNR/15/HAWKE/269) and included approval to obtain de-identified EMR patient outcome data.

## **Data analysis**

Data was analysed using IBM SPSS v.22 (Corp., 2013). Descriptive statistics (frequency and percentages) were used to summarise data. For normally distributed data, mean and standard deviations are presented. Group comparisons were performed for non-parametric data (Pearson Chi Square and Mann-Whitney U tests) using the IBM SPSS program (IBM SPSS v.21, Chicago IL USA). Free text responses were examined with content analysis. For the study statistical significance was  $p < .05$ .

Qualitative (observational) data were analysed and organised thematically in an NVivo (version 10) electronic database (QSR International, 2017). Thematic analysis was systematic and guided by Gibbs's framework which includes: 1) transcription and familiarisation; 2) code building; 3) dis/confirmatory theme development; and 4) data consolidation and interpretation (Gibbs, 2007; Lichtman, 2010). The authors discussed, reviewed and agreed on the coding and themes.

## **RESULTS**

### **Medical record audit**

1569 patients' data were reviewed for the medical record audit; 819 patients were treated in the open-bay ward and 750 were treated in the new single room ward. There were no statistical significant differences between the groups for baseline characteristics and for length of stay, mortality rate or hospital disposition (Table 1).

[Table 1]

There was no statistical significant difference for MRSA rates between the care delivered in the open-room ward and the single room ward (Table 2). Hospital acquired adverse event (MRSA

infection, pressure injury or fall) rates were similar for the open-bay ward (n=35) when compared with the single room ward (n=33). There was a trend towards fewer unwitnessed falls (n=9) in the single room ward compared with the open-bay ward (n=16). While also not statistically significant, there were more pressure injuries for patients who were treated in the single rooms (Table 2).

[Table 2]

There were fewer bedside emergency call buzzer activations by nurses in the single room ward. In the open-bay ward, the emergency buzzer was activated 15 (1.8%) times during the study period, while in the single room ward, this emergency call buzzer was activated only 3 (0.4%) times.

### **Nurses' survey**

There was a 74% (n=28) response rate for the nurse survey (Table 3). The majority were registered nurses with mean 10.1 (9.6) years' experience and either an undergraduate and or a postgraduate degree. The majority of respondents had worked in both the open-bay and single room wards (27 of the 28 nurses had worked in the open bay ward). All but one nurse had at least one year experience in the open-bay ward. The majority reported that their practice had changed in response to working in the single room ward. Many nurses reported that the reduced ability to observe patients contributed to the change in their practice.

[Table 3]

Nurses reported greater satisfaction in providing nursing care in the single room ward with the majority satisfied with the ward design. The majority perceived that single room wards benefitted patients and the delivery of care and that the new design improved patient satisfaction and infection rates. Furthermore, they reported that the ability to deliver care in this environment was as a result of teamwork and careful patient-room allocation.

### **Medical doctors' survey**

There were 12 (response rate: 50%) respondents for the orthopaedic medical doctor survey with a mean 10.2 (9.9) years' experience (Table 4). The respondents were; surgeons (board certified orthopaedic surgeons), registrar/trainee (orthopaedic fellows) and intern/residents. The majority had previously worked in the open-bay ward. All respondents reported they were satisfied with the new single room design compared to the open-bay wards. The majority reported that patients were safer in single rooms. One junior medical officer reported patients were somewhat safer and commented that patients were 'at increased risk of falling'. The majority perceived that patients had better outcomes when cared for in single rooms. Factors which were perceived by respondents to benefit patients included: better privacy, improved infection control and better sleep/rest. Four respondents were concerned that a reduction in supervision may place patients at risk of harm.

[Table 4]

### **Patients' survey**

118 patients (16% response rate) responded to the survey (Table 5). 60% (n = 67) were female and the mean age was 63 (SD 18) years. Median length of stay in the single room ward reported by patients at the time they completed the survey was 7 (IQR 4-10) days. The most common reason for admission was spinal injury/surgery. The majority had experienced care in an open-bay ward previously (n=92 (78%)). Overall, patients reported high levels of satisfaction with care in the single room ward environment specifically the quality of care, the timeliness of care, communication with health professionals and accessibility of health professionals. The majority of patients reported feeling safe in a single room.

[Table 5]

### **OBSERVATIONS**

Non-participant observations were conducted with five nurses. Data saturation was reached after 21.5 hours. Data findings became repetitive after 16.5 hours. A further four hours were



conducted to confirm data saturation. Three themes emerged from the data: i) teamwork and coordination of care; ii) visualising the patient; and iii) routine and structure.

### ***Teamwork and coordination of care***

It was evident during observations that the efficiency of nursing care delivery in the single room environment was reliant on teamwork and coordination of care. Team work enabled each nurse to coordinate care with another nurse. Many interactions were observed when nurses worked with each other to better support practice and deliver essential care. The team approach readily enabled nurses to obtain assistance with procedures such as medication administration, patient care activities (e.g. manual handling) or decision making. This enhanced the timeliness and efficiency of care:

*Two nurses began discussing how to administer an uncommon medication with colleague planning how to administer the intravenous medication (Observation 3, Observer)*

*Team work was important and provided opportunistic moments for support. For example the team leader offered to assist with a patient bed sponge. (Observation 1, Observer)*

During nurses' meal break times, the accessibility of nursing colleagues decreased and as a result nurses spent more time searching the ward for team members. The following observation illustrates this:

*"It is difficult to find someone when your team-mate goes for a break. We try to get the checks done before they all go". (Observation 4, RN)*

*One member of the team allocated to eight beds went in search for a second nurse to check [medication], walking around the 28 bed ward looking for another nurse as her allocated team member had gone for a meal break. (Observation 3, Observer)*

Given the single room layout, and the distances needed to travel to provide care, time management was perceived to be important to ensure patient safety and reduce patient care delays. During many observations, the majority of nurses were observed to coordinate their meal breaks while scheduling priorities of impending care. A teamwork approach appeared to be critical for a single room ward to enable the prioritisation and management of timely care. A most important element of patient safety was the teamwork approach to handover (handoff). All nurses perceived it was important to obtain a handover for all patients prior to commencing the shift in addition to the bedside handover for individual teams. All nurses rostered on the shift gathered in the ward meeting room to receive ward handover which was conducted by the team leader from the previous shift. This general handover was observed to give nurses confidence to attend to patients that they were not allocated (assigned) to care for. For example:

*“We have handover for all thirty patients so that we can be aware of the condition of all the patients on the ward, even the patients we aren’t looking after. This allows us to feel more confident in checking medications and assisting each other to give the care”.*

*(Observation 3, RN)*

Once the ward handover was complete nurses obtained a bedside handover. Two nurses were allocated (assigned) eight to ten patients and were then observed to receive a more detailed handover at the bedside. In addition, there was a team leader who did not have a patient allocation and therefore was available to assist. In contrast to day shift, night duty observations identified that nursing teams were allocated ten to fifteen patients and the night duty team leader was rostered a patient load of four to five patients to allow them to be available to coordinate care.

Nurses were observed using various methods to locate one another around the ward. On some occasions, nurses would be seen walking the corridors, looking into each room in an attempt to

locate their colleagues. However, on many occasions a call bell system was used by nurses to visually display the room number in which they were providing care.

*The nurse wanted to update their team member and leaves the single room in search of the team partner. The nurse does not call out instead goes walking along the corridor looking for their partner nurse and checks the call screen. Call screen displays [room number] in white with no alarm heard and so enters the room to find team partner.*

*(Observation 3, Observer)*

During many observations, nurses were observed to press the call bell to ensure their team members were aware of their location. To notify team members when the nurse pressed the call button, the room number would display on screens around the ward, although no audible alert was activated in contrast to a patient activated call bell. As a result nurses frequently used the call bell system as a means of communication to enable the more timely coordination of care. The teamwork and coordination approach appeared to be essential to ensure streamlined delivery of care and ward activities.

### ***Visualising the patient***

It became evident during all observations that for patient safety nurses actively ensured they took the time to observe their patients. Patients were visualised with significant regularity on the shift. Nurses took any opportunity to visualise patients specifically when walking in the corridor.

*While walking to the medication room, the nurse looks into each room whilst walking up the corridor. The nurse stepped into the room (bed 17) and states “keep eating your dinner”. (Observation 4, Observer)*

*“Because we can’t see the patients as easily in this ward, we make sure we do hourly rounds to check on the patients”. (Observation 1, RN)*

Nurses actively looked into patients rooms while attending to other duties as this appeared to be the most efficient way to manage the single rooms and ensure patient safety. Nurses attended to documentation and planning at workstations in peripheral locations around the ward to remain closer to the rooms of the patients they were allocated. For all nurses regular visualisation of patients was seen to be important.

*“The peripheral desks allow us to be located closer to the patients and their family should we be needed for anything and so we can see them all the time”. (Observation 4, RN)*

Nurses preferentially located themselves closer to their allocated patient load aiding them to attend to patients quickly for usual care tasks and regular observation. To enhance visualisation further the nurses developed a tool to assist with allocating patients to rooms appropriate to their level of risk. Patients who they deemed to be at high risk of deterioration were allocated to rooms that were more readily visualised during a normal working day.

*“We don’t need to move patients for gender reasons anymore, but we do move patients if we feel they need to be seen more often, the acuity and dependency score helps us to decide which bed is most appropriate for their needs” (Observation 3, RN)*

*“The acuity and dependency scoring system allows us to have a quick idea how at risk a patient is and whether that team will need more assistance from the team leader” (Observation 5, RN)*

The room based allocation was determined by patient risk, acuity (medical deterioration) and dependency (nursing workload). The patients who had higher acuity scores were allocated (or transferred) to rooms closer to the nurses’ station and common staff thoroughfares. Risks were mitigated by the frequent visualisation of patients.

### ***Routine and structure***

To ensure the routine flow and structure in the new single room ward the determination of resources, equipment, team allocation and routines were all considered prior to moving. Nurses discussed the importance of mirroring the location for stores, equipment and medical record documents in the new single room ward. During observations all nurses discussed how important this had been to streamline the transition and minimise the impact of change. For example:

*“When we moved to this ward, we tried to keep as much the same as possible, we have the same phone list, the forms are all stored on the shelf in the same order and we have the dressings all laid out the same as we did in the old ward, this helps us to find things quickly and easily in a new environment”. (Observation 3, RN)*

Nurses spoke of the importance of familiarity in the speed and delivery of patient care in the new ward. For example, to assist with efficiency and familiarity the paperwork, store room and equipment and phone numbers were kept in the similar location or arranged in a similar way to the previous ward. This enabled nurses to locate these resources quickly. Frequently throughout the observations nurses were seen to go directly to a location to obtain an item and find it immediately.

While there was only one main nursing station in the ward but there were peripheral work stations located throughout the ward. To facilitate timely care frequently used stock, such as personal protective equipment (PPE), pads, tape and wipes were kept in drawers at the peripheral work stations. The drawers were replenished by nurses during quiet periods.

*“It [workstation] saves us walking backwards and forward to the storeroom every time we need something”. (Observation 4, RN)*

The daily routine within the ward was well structured and routine was consistent during study observations. Nurses used a structured time planner to pre-plan and keep track of tasks that

were required to be completed throughout the shift and took advantage of spare time to complete non-urgent tasks such as tidying up, restocking, documentation, daily ward safety checklists.

*“I think being prepared early is better than being not prepared at all”. (Observation 5, RN)*

Nurses were frequently observed to multitask to save time when having to traverse the ward. Many activities were undertaken concurrently and even when walking to the central ward pharmacy room, nurses would attend to other activities such as delivering a water bottle, checking on a patient or discussing a clinical issue with the team leader. These activities gave shape to the routine and structure of everyday work in the changed environment of the single room ward.

## **DISCUSSION**

This study demonstrated that caring for patients in single room wards compared to open-bay wards did not increase the rate of deterioration, length of stay or the incidence of adverse events. The data identified that the rate of falls reduced, while pressure injuries slightly increased, however neither were statistically significant. The low rate of hospital-acquired MRSA reduced further but this was not statistically significant.

The study revealed that the clinicians’ main concerns were related to patient safety and the potential reduced ability to quickly identify patient deterioration. However, study observations revealed that nurses positioned themselves at peripheral workstations adjacent to the rooms of the patients they were allocated to care for. This meant that nurses were more likely to be located close to the patient and therefore detect early deterioration. Further, the nurses had developed a tool to allocate patients’ at high risk of deterioration to rooms that were more readily visualised. These two interventions together assisted to improve the safety of patients. The reduction in emergency call bell activation rates suggest a trend in reduced patient risk.

Future single room ward designs need to accommodate peripheral nurse workstations to ensure they are located to support the visualisation of patients and timely delivery of care.

All clinicians perceived the change in environment to be a positive experience which resulted in increased satisfaction. Nonetheless, nurses perceived caring for patients in single room meant that they were worked harder and were required to be more strategic in the prioritisation and coordination of care. All clinicians perceived that the single room environment resulted in improved wellbeing and safety.

In this study **the majority of nurses reported that delivering care in single rooms occurred with fewer interruptions than open-bay room wards.** The reduction in interruptions and distractions contributed to a perception of improved patient outcomes as nurses were able to perform their tasks with more focus and may have contributed to nurses' reports of high satisfaction. Further nurses perceived that there was a decrease in patient bed movement around the ward.

Patients reported high satisfaction with care when they were treated in a single room ward and reported increased wellbeing, sleep and privacy, communication, accessibility to clinicians and feeling safe. The patient care in single rooms did not appear to negatively impact patient wellbeing. In fact, building single room wards could go some way to improving the overall hospital experience.

In this study, nurses reported the use of an acuity system tool to ensure patients at risk of deterioration were readily visible during daily activities. The nurses reported that this tool identified patients who were at risk of deterioration and then they were able to appropriately allocate them to more visible rooms. While poor visualisation of patients was perceived as a significant risk in a single room ward layout the implementation of this acuity system enabled patient safety to be maintained as it had been in the open bay room ward.

The findings of many studies (Allegranzi, 2011; Bloemendaal et al., 2009; Bonizzoli et al., 2011) suggest that MRSA cross-contamination would be reduced if there were more single room wards. This study supports these findings, while not statistically significant, the rate of hospital

acquired MRSA reduced after the move to a single room ward. A larger study could explore this outcome further.

## **LIMITATIONS**

There were some limitations of this study that warrant consideration. The study was conducted in a single site in one specific discipline and may not reflect the views of clinicians and patients in other health settings. The sample size of orthopaedic surgeons was small and may not reflect the views of all medical clinicians. In addition the experience and perspective of patients whose first language was not English was not included; this may have revealed some important information in relation to perceived safety for a potentially vulnerable patient group. The observational data were limited to 24 hours which may not reflect the true activities and behaviours of all nurses. The observations excluded weekends, which may have limited the opportunity of some clinicians to participate in the study. Consequently, only the perspectives and work practices of some nurses were observed. In addition work routines may have differed during weekends. The findings may not be truly representative. Surveys only provide respondents with the opportunity to report their views and may not reflect actual behaviour or attitudes during the delivery of care. Consequently, survey data may only bring to the surface a particular view point and may not be representative of all.

## **CONCLUSION**

The findings of this study highlight that **both clinicians and patients were supportive of a single room ward design compared to an open-bay design**. More specifically, increased patient satisfaction due to privacy, improved sleep patterns and feelings of safety was reported. Clinicians' concerns about safety were unsubstantiated by the study and instead there was reduced or insignificant improvement in the number of adverse events.

This study demonstrated that caring for patients in a single room ward did not increase the rate of deterioration, length of stay or the incidence of adverse events. Further, patients were more



satisfied, better rested and had a higher sense of wellbeing due to increased privacy. The team work approach and peripheral work stations mitigated any potential problems with the single room ward layout and was perceived to improve efficiency and timeliness of care despite geographical challenges. Overall the single room ward design was preferred by clinicians and patients when compared to an open-bay ward.

### **AUTHORS CONTRIBUTIONS**

MD, MF and RH conceived the study and developed the protocol, MD collected and analysed the data, RE reviewed the data analysis and MD, MF and RE wrote the manuscript.

### **ETHICAL APPROVAL**

The researchers obtained approval from the local Human Research Ethics Committee (LNR/LNR/15/HAWKE/269) and assessed the study to be of low or negligible risk to both patient and health professional participants.

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## REFERENCES

- Allegranzi, B. (2011). Measures to be taken: Hand hygiene, isolation, hospital cleaning. *Clinical Microbiology and Infection*, 17, S105. doi:<http://dx.doi.org/10.1111/j.1469-0691.2011.03557.x>
- Bloemendaal, A. L., Fluit, A. C., Jansen, W. M., Vriens, M. R., Ferry, T., Argaud, L., et al. (2009). Acquisition and cross-transmission of *Staphylococcus aureus* in European intensive care units. *Infection Control & Hospital Epidemiology*, 30(2), 117-124. doi:<http://dx.doi.org/10.1086/593126>
- Bonizzoli, M., Bigazzi, E., Peduto, C., Tucci, V., Zagli, G., Pecile, P., et al. (2011). Microbiological survey following the conversion from a bay-room to single-room intensive care unit design. *Journal of Hospital Infection*, 77(1), 84-86. doi:<http://dx.doi.org/10.1016/j.jhin.2010.07.018>
- Chaudhury, H., Mahmood, A., & Valente, M. (2006). Nurses' perception of single-occupancy versus multioccupancy rooms in acute care environments: An exploratory comparative assessment. *Applied Nursing Research*, 19(3), 118-125. doi:<https://doi.org/10.1016/j.apnr.2005.06.002>
- Cheng, V. C., Tai, J. W., Chan, W. M., Lau, E. H., Chan, J. F., To, K. K., et al. (2010). Sequential introduction of single room isolation and hand hygiene campaign in the control of methicillin-resistant *Staphylococcus aureus* in intensive care unit. *BMC Infectious Diseases*, 10, 263. doi:<http://dx.doi.org/10.1186/1471-2334-10-263>
- Chu, R. Z. (2017). Preventing in-patient falls: The nurse's pivotal role. *Nursing*, 47(3), 24-30. doi:10.1097/01.nurse.0000512872.83762.69
- Corp., I. (2013). IBM SPSS Statistics for Windows, Version 22.0. (Version 22). Armonk, NY: IBM Corp.
- Cunningham, D. J., Kavolus, J. J., 2nd, Bolognesi, M. P., Wellman, S. S., & Seyler, T. M. (2017). Specific Infectious Organisms Associated With Poor Outcomes in Treatment for Hip Periprosthetic Infection. *J Arthroplasty*, 32(6), 1984-1990. doi:10.1016/j.arth.2017.01.027
- Finkelstein, R., Eluk, O., Mashiach, T., Levin, D., Peskin, B., Nirenberg, G., et al. (2017). Reducing surgical site infections following total hip and knee arthroplasty: an Israeli experience. *Musculoskelet Surg*, 101(3), 219-225. doi:10.1007/s12306-017-0471-2
- Flynn, B., Kellagher, M., & Simpson, J. (2010). Workload and workforce planning: tools, education and training. *Nursing management (Harrow, London, England : 1994)*, 16(10), 32-35.
- Gibbs, G. (2007). *Analyzing qualitative data*. London: Sage.
- Janssen, P. A., Klein, M. C., Harris, S. J., Soolsma, J., & Seymour, L. C. (2000). Single room maternity care and client satisfaction. *Birth*, 27(4), 235-243.
- Lawson, B., & Phiri, M. (2000). Hospital design. Room for improvement. *The Health service journal*, 110(5688), 24-26.
- Lenhart, V., Stickler, K., Kriz, E., Angerler, G., & Tucek, G. (2008). Results from a ESBL contactscreening in a tertiary care hospital. [German] Ergebnisse eines ESBL mitpatientenscreenings in einem schwerpunktkrankenhaus. *Krankenhaushygiene und Infektionsverhütung*, 30(1), 8-10. doi:<http://dx.doi.org/10.1016/j.khinf.2007.11.001>
- Lewis, J. A., Miller, D. R., & Davies, S. G. (2004). Osteomyelitis complicating three types of traumatic hand wound. *J Wound Care*, 13(7), 281-283. doi:10.12968/jowc.2004.13.7.26640
- Lichtman, M. (2010). *Qualitative research in education: A users guide* (2nd ed.). Thousand Oaks, California: Sage.

- Mandl, L. A., Huang, W. T., Lee, J., Bailey, T., Edwards, D., Quinlan, P., et al. (2013). Falls among hospitalized orthopedic patients: A prospective case-control study. *Arthritis and Rheumatism*, 65, S817. doi:<http://dx.doi.org/10.1002/art.38216>
- Meredith, J. L., Jnah, A., & Newberry, D. (2017). The NICU Environment: Infusing Single-Family Room Benefits into the Open-Bay Setting. *Neonatal Netw*, 36(2), 69-76. doi:10.1891/0730-0832.36.2.69
- Meyer, E., Schwab, F., & Gastmeier, P. (2010). Nosocomial methicillin resistant staphylococcus aureus pneumonia - Epidemiology and trends based on data of a network of 586 german icus (2005-2009). *European Journal of Medical Research*, 15(12), 514-524.
- National Health Service. (2008). *Ward layouts with single rooms and space for flexibility* London: National Health Service.
- QSR International. (2017). NVIVO. Doncaster, Victoria, Australia: QSR International.
- Roberts, K., Khosa, P., Singh, S., Son, C., Eagan, J., & Sepkowitz, K. (2011). Time to isolation-every minute counts. *American Journal of Infection Control. Conference: 38th Annual Educational Conference and International Meeting of the Association for Professionals in Infection Control and Epidemiology, Inc., APIC*, 39(5), E88-E89. doi:<http://dx.doi.org/10.1016/j.ajic.2011.04.162>
- Sadatsafavi, H., Niknejad, B., Shepley, M., & Sadatsafavi, M. (2017). Probabilistic Return-on-Investment Analysis of Single-Family Versus Open-Bay Rooms in Neonatal Intensive Care Units-Synthesis and Evaluation of Early Evidence on Nosocomial Infections, Length of Stay, and Direct Cost of Care. *J Intensive Care Med*, 885066616689774. doi:10.1177/0885066616689774
- Sadatsafavi, H., Niknejad, B., Zadeh, R., & Sadatsafavi, M. (2016). Do cost savings from reductions in nosocomial infections justify additional costs of single-bed rooms in intensive care units? A simulation case study. *J Crit Care*, 31(1), 194-200. doi:10.1016/j.jcrc.2015.10.010
- Skally, M., Roche, F., Donlon, S., Farrell, T., Twohig, M., Humphreys, H., et al. (2009). Surveillance of methicillin-resistant Staphylococcus aureus within Irish intensive care units. *Clinical Microbiology and Infection*, 15, S543-S544. doi:<http://dx.doi.org/10.1111/j.1469-0691.2009.02858.x>
- United States Bone and Joint Initiative. (2014). *The Burden of Musculoskeletal Diseases in the United States (BMUS)*. Retrieved from United States:
- van de Glind, I., de Roode, S., & Goossensen, A. (2007). Do patients in hospitals benefit from single rooms? A literature review. *Health Policy*, 84(2-3), 153-161. doi:10.1016/j.healthpol.2007.06.002
- Wayne, G. (2014). Florence Nightingale's Environmental Theory. Retrieved from <http://nurseslabs.com/florence-nightingales-environmental-theory/>

Table 1. Comparison of characteristics and outcomes for patients managed in open-ward and single room ward

Characteristic/outcome	Open-ward (n = 819)	Single room (n = 750)	P value
Female gender, n (%)	430 (51)	366 (49)	.561
Male gender, n (%)	389 (49)	384 (51)	
Age, years, mean (SD <sup>a</sup> )	63.6 (21.4)	61.5 (21.8)	.053
Diagnosis on admission to ward, n (%)			
Lower limb injury	293 (35.8)	296 (39.5)	.598
Spinal/vertebral/pelvis injury	204 (24.9)	180 (24.0)	
Upper limb injury	148 (18.1)	127 (16.9)	
Head injury/cognitive impairment	41 (5.0)	27 (3.6)	
Infection/sepsis	5 (0.6)	5 (0.7)	
Other	128 (15.6)	115 (15.3)	
Ward length of stay, days, median (IQR <sup>b</sup> )	2.0 (1.0-5.0)	2.0 (1.0-5.0)	.698
Hospital length of stay, days, median (IQR)	6.0 (3.0-10.0)	6.0 (3.0-10.0)	.226
Discharge destination, n (%)			
Home	601 (73.4)	567 (75.6)	.311
Transfer/other facility	198 (24.2)	168 (22.4)	.406
Death	20 (2.4)	15 (2.0)	.664

<sup>a</sup> standard deviation, <sup>b</sup> interquartile range

Table 2. Adverse event data (n = 1569)

Event	Open-ward N = 819	Single room N = 750	P value <sup>a</sup>
Hospital acquired MRSA infections, n, (%)	3 (0.4)	0 (0)	0.251
MRSA present on admission, patients, n (%)	19 (2.3)	16 (2.1)	0.865
Hospital acquired pressure injuries, n (%)	13 (1.6)	19 (2.5)	0.243
Falls in hospital, n (%)	19 (2.3)	14 (1.9)	0.599
Unwitnessed fall	16 (84.2)	9 (64.3)	0.491
Second fall	2 (0.24)	2 (0.27)	0.082
Medical deterioration calls <sup>b</sup> , n			
Rapid response	178	77	N/A
Clinical review	588	349	N/A

<sup>a</sup>Pearson's Chi Square, <sup>b</sup>number of medical emergency calls for medical deterioration during study period

Table 3. Nursing survey (n = 28)

	N (%)
<b>Level of nurse</b>	
Registered nurse	24 (86)
Enrolled nurse (Licensed practical nurse)	2 (7)
Assistant in nursing (certified nursing assistant)	2 (7)
Female gender, n (%)	24 (89)
Nursing experience, years, mean (SD <sup>a</sup> )	10.1 (9.6)
Full-time employment status, n (%)	14 (50)
<b>Education qualifications, n (%)</b>	
Bachelor degree	20 (71)
Hospital training certificate	3 (14)
Diploma (enrolled nurse)	3 (7)
Certificate (assistance in nursing)	2 (7)
Postgraduate certificate	13 (46)
<b>Open- ward experience, year range, n (%)</b>	
Never experienced	1 (4)
1-4	13 (46)
5-9	6 (21)
10-14	3 (11)
15-19	1 (4)
20+	4 (14)
<b>Increased satisfaction with nursing in single room ward, n (%)</b>	

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Never	0 (0)
Hardly ever	1 (4)
Sometimes	7 (25)
Most of the time	11 (39)
Always	9 (32)
Advantages of single room ward design, n <sup>b</sup>	
Better patient satisfaction	26
Better infection control	25
Ward design	14
More time with individual patients	10
Teamwork	8
Increased privacy	6
Care provided in a timely manner	4
Patient specialty type	2
Confidence in caring for patients in single rooms, n (%)	
Not at all	0 (0)
A little	1 (4)
Moderately	2 (7)
Quite a lot	8 (29)
Very confident	17 (61)
Adequacy of skills to deliver care for patients in single rooms, n (%)	
Not at all	0 (0)
Hardly ever	1 (4)

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Sometimes	7 (25)
Most of the time	11 (39)
Always	9 (32)

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<sup>a</sup>standard deviation, <sup>b</sup>content analysis of free text response



Table 4. Medical doctors' survey (n = 12)

Characteristic	Statistic
Respondents, n (%)	
Intern	4
Resident	2
Registrar (orthopaedic fellow)	1
Surgeon (board certified medical doctor)	5
Experience, years, median (IQR <sup>a</sup> ) [range]	4.25 (0.7 - 15), [0.2 – 30]
Female gender, n (%)	0 (0)
Open- ward experience, n (%)	11 (92)
Satisfaction with single room ward, n (%)	
Mostly	7 (58)
Definitely	5 (42)
Perception of patient safety in single rooms, n (%)	
Somewhat	1 (8)
Mostly	6 (50)
Definitely	5 (42)
Perception of improved patient outcomes in single rooms, n (%)	
Somewhat	1 (8)
Unaffected	3 (25)
Mostly	8 (67)
Perception of patient advantage in single rooms, n (%)	
Somewhat	3 (25)
Unaffected	1 (8)

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Mostly	5 (42)
Definitely	3 (25)
Perception of patient disadvantage in single rooms, n (%)	
Not at all	5 (42)
Somewhat	5 (42)
Unaffected	2 (8)

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<sup>a</sup> interquartile range

Table 5. Patients' survey (n = 118)

Item	n (%) <sup>a</sup>				
	Not at all	Hardly ever	Sometimes	Most of the time	Always
Satisfaction with environment	5 (0.5)	8 (0.5)	11 (9)	43 (37)	48 (53)
Perception of privacy	3 (0.5)	0	1 (0.5)	27 (24)	87 (75)
Satisfied with care	1 (0.5)	0	0	29 (25)	88 (74.5)
Adequacy with sleep	3 (2.5)	4 (2.5)	9 (8)	56 (48)	45 (39)
Care provided in a timely manner	1 (0.5)	0	4 (3.5)	41 (35)	72 (61)
Satisfaction with access to nurses	0	0	4 (3)	34 (29)	80 (68)
Felt safe	0	0	0	13 (11)	105 (89)
Satisfied with quality of care	0	1 (0.5)	0	26 (22)	91 (77.5)
Satisfaction with communication with nurses	0	1 (0.5)	5 (4)	36 (30.5)	76 (65)

<sup>a</sup>up to 3 missing data for some items