Systematic Review on
Safe Nurse-to-patient Ratio

Submitted to the Association of Hong Kong Nursing Staff

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Project Title

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List of Abbreviations

AACAP	American Academy of Child and Adolescent Psychiatry
AHKNS	Association of Hong Kong Nursing Staff
ANF	Australian Nursing Federation
APNA	American Psychiatric Nurses Association
ASPAN	American Society of PeriAnesthesia Nurses
AWOHNN	The Association of Women's Health, Obstetric & Neonatal Nursing
BACCN	British Association of Critical Care Nurses
BAPM	British Association of Perinatal Medicine
BCNU	British Columbia Nurses' Union
BMA	British Medical Association
CC3N	Critical Care Networks National Leads Group
CINAHL	Cumulative Index to Nursing and Allied Health Literature
DoH	Department of Health, the United Kingdom
ERIC	Education Resources Information Center
FTE	Full-time equivalent
ICU	Intensive Care Unit
NANN	National Association of Neonatal Nurses
OR	Odds ratio
PICS	Paediatric Intensive Care Society
QIS	Qualified in Specialty
RCA	Royal College of Anaesthetists
RCMW	Royal College of Midwives
RCN	Royal College of Nursing
RCOG	Royal College of Obstetricians and Gynaecologists
RCP	Royal College of Psychiatrists
RCPCH	Royal College of Paediatrics and Child Health
RN	Registered nurse
VAP	Ventilator-assisted associated pneumonia
VDHS	Victorian Department of Human Services
WHO	World Health Organization
WTE	Whole-time equivalent

Appendix

Executive Summary

The global and local call for safe staffing

World Health Organization points out that both developed and developing countries are experiencing a shortage of all types of health workers, particularly nurses.[1] The shortage of nurses in high-income countries continues to intensify because of the ageing workforce and the increasing burden of chronic and degenerative diseases. Since early 2000, the shortage of nurses has been worsening in Hong Kong since the closure of diploma nursing programs for enrolled nurses without corresponding expansion of university training programs for registered nurses.[5] Despite the recent effort to expand and re-open training courses for nurses,[6] nurses in public hospitals are facing an unprecedented workload and stress. The turnover rate continues to rise from 3.2% in 2006/07 to 5.4% in 2010/11.[7] Recently, the Hospital Authority in Hong Kong has been taking initiatives to retain nurses but the call for safe staffing levels has not been adequately answered. A local survey reported that each nurse in public hospitals had to provide direct care to at least 10 patients during daytime.[8]

Recent emerging evidence that links nurse staffing and quality of care have facilitated a greater call for safe staffing. A number of staff planning methods have been proposed to determine the size of the nursing workforce.[12] Controversies continue to exist regarding the use of nurse-to-patient ratio to safeguard the quality of patient care.[18] This review aimed to evaluate all available evidence regarding nurse-to-patient ratios in the hope of providing a clearer picture of how staffing ratios affected patient outcomes.

Safe nurse-to-patient ratios

Nurse-to-patient ratio is a frequently used indicator of safe staffing. Regulation of minimum nurse-to-patient ratios is now in effect in California,[20, 22] the United States and Victoria[24] and New South Wales,[25] Australia. The mandated ratio in medical-surgical units is 1:5 in California and 1:4 in Victoria and New South Wales. International clinical guidelines (see Table 9 for details; pp. 22) also suggest one nurse to take care of 4 to 5 general medical-surgical patients during day shifts. The nurse-to-patient ratios recommended by clinical guidelines represent the service standards based on professional judgment and a range of factors such as patient dependency and geographical setting. In brief, the respective recommended nurse-to-patient ratios in various clinical settings are:

- Adult intensive care 1:1-1:2
- Child intensive care 2:1-1:2
- Neonatal care 1:1-1:2
- General pediatrics 1:3-1:5
- Antepartum 1:4-1:8
- Labor and delivery: 1:1-1:2
- Postpartum 1:4-1:8
- Adult psychiatric 1:4-1:7
- Child and adolescent psychiatric 1:1-1:4
- Post-anesthesia recovery 2:1-1:2

It is highly challenging to determine which nurse-to-patient ratio represents the safe staffing level because of methodological challenge.[127] It explains the dearth of studies that examined the effectiveness of mandated nurse-to-patient ratios. Despite limited number of studies, it would be misleading to conclude that number of nurses does not matter. The common use of nurse-to-patient ratios as service standards is supported by empirical evidence that establishes a link between staffing ratio and patient outcome. In order to confirm the use of a certain nurse-to-patient ratio as quality benchmark, this systematic review aimed to pool all the best available evidence from the literature.

Review of nurse-to-patient ratios and patient outcomes

Despite the long-standing interest in studying nurse staffing pattern, previous published reviews[51-56] which evaluated all types of staffing measures have failed to provide a clear conclusion of how nurse-to-patient ratio itself impacted patient outcome. This systematic review answered this question by only selecting studies which used nurse-to-patient ratio. This review was more informative than other reviews in a sense that a meta-analysis was applied to quantify the effect of additional nursing staff.

Objectives

The primary objective was to address specific research questions regarding the association between nurse-to-patient ratio and a range of patient outcomes, including mortality, length of hospital stay, and a range of nurse-sensitive patient outcomes, including medication errors, failure to rescue, pneumonia, urinary tract infection, nosocomial infections, pressure ulcer, patient fall, pulmonary failure, unplanned

extubation, and Methicillin-resistant Staphylococcus aureus acquisition.

Search strategy and data synthesis

Potential studies were identified in major electronic databases and reference lists of the published reviews. A combination of pre-defined keywords and free-texts were used to search for potential eligible studies. A study was considered eligible if it included nurse-to-patient ratio as the staffing measure and explored its relationship with at least one of the pre-defined patient outcomes. Unless otherwise specified, a "nurse" referred to all types of nursing staff who may be a registered nurse, enrolled nurse/licensed practical (vocational) nurse, and sometimes nursing assistants. Registered nurse-to-patient ratio referred to the average number of patients taken care by a registered nurse.

Meta-analysis was performed to quantify the strength of association between nurse-to-patient ratios and patient outcomes. Studies conducted in any hospital units were included in the meta-analysis. Studies conducted in general medical-surgical and intensive care units were then examined individually. A subgroup analysis repeated the procedure by selecting studies using registered nurse-to-patient ratios.

Results

A total of 2,546 references were screened. Forty-two studies meeting the inclusion criteria were selected for the review. Majority of the studies (81%) were retrospective and ascertained data from large hospital databases or surveys.

The results demonstrated that an additional nurse per patient day was associated with lower risk of hospital mortality (OR=0.86; 95% CI 0.78, 0.96). A higher nurse-to-patient ratio was also associated with lower risk of failure to rescue (OR=0.86; 95% CI 0.79, 0.94), pressure ulcer, and pneumonia (OR=0.51; 95% CI 0.30, 0.87). The relationship between nurse-to-patient ratio and mortality still held within studies using registered-nurse patient ratios (OR=0.87; 95% CI 0.80, 0.96). Further exploration found that the effect of an additional nurse per patient day on mortality was mainly contributed by studies from medical-surgical units. Mortality in intensive care units was not reduced with additional nurse staffing (OR=0.93; 95% CI 0.66, 1.30).

Preliminary findings also suggested an inverse relationship of staffing ratios with length of hospital stay in intensive care units (27.6% reduction in length of stay;

95% CI -45.9%, -9.4%), pulmonary failure (OR=0.31; 95% CI 0.24, 0.40), patient falls, and Methicillin-resistant staphylococcus aureus acquisition. The relationships of staffing ratios with length of hospital stay in medical-surgical units, nosocomial infections, unplanned extubation, and medication errors were inconclusive.

General discussion

The results of this review confirms that nurse-to-patient ratio was a sensitive indicator of patient outcome. The association between a higher nurse-to-patient ratio and reduced hospital mortality in medical-surgical units is highly prominent. The association is less clear in intensive care units. The insignificant results are likely confounded by severity of illness.[109] It has been also suggested that the number of nurses with specialized qualification and experience in critical care nursing determines the mortality outcome.[91,96] The insignificant association with hospital mortality in critical care setting by no means implies that nurse-to-patient ratio is insignificant. Nurse-to-patient ratio in critical care setting is shown to be more relevant in other patient outcomes. Fewer ICU nurses may lead to longer length of stay[68, 74] and higher risk of postoperative complications,[75] central venous catheter-associated bloodstream infection,[79] unplanned extubation,[85] and methicillin-resistant staphylococcus aureus infection.[99]

The inverse relationship between registered nurse-to-patient ratio and hospital mortality further strengthens the important role of registered nurses in the provision of safe nursing care. Based on this finding, the re-opening of training courses for enrolled nurses in Hong Kong should be carefully considered and monitored. There is a clear mismatch between the development of educational programs and clinical needs in Hong Kong. Long-term manpower planning should focus on the training for registered nurses.

This review presented the best available evidence in support of using nurse-to-patient ratio to safeguard patient outcomes. The current nurse-to-patient ratios in public hospitals are far below international standards. This review has taken the first local initiative to recommend safe nurse-to-patient ratios in various clinical settings (Table 16, pp. 49; Chapter 5, pp. 56). The recommended ratios are in alignment with the international clinical guidelines. None of the selected studies in the review investigated staffing in psychiatric units. More studies should be conducted to assess psychiatric staffing ratios in relation to psychiatric-specific outcomes (eg, hours of physical restrain and hours of seclusion).[117]

Supervisory nurse staffing

The calculation of nurse-to-patient ratios only include nurses who provide direct care to patients. No research studies in general medical-surgical units or psychiatric units that directly address frontline nursing staff-to-supervisor ratio could be found; thus, its relation to morbidity and mortality in general medical-surgical units and psychiatric units could not be assessed. Nevertheless, some clinical guidelines have proposed standard staffing level of supervisory nurses. For instance, a senior nurse should be assigned to an adult critical care unit with more than 6 beds. One WTE consultant midwife is suggested to oversee 900 low-risk women under midwifery care per year. Nurse managers or charge nurses are considered key personnel to oversee clinical operations, to maintain quality of care, and to retain frontline nurses. Their clinical experience and knowledge allow them to make effective and autonomous decisions in response to clinical situations. However, the role of nurse managers in the provision of quality care remains to be anecdotal evidence. Future studies should scientifically quantify their roles and leadership attributes that may promote the quality of care provision.

Recommendations

This review has taken the first local initiative to recommend safe nurse-to-patient ratios in various clinical settings. The recommended ratios are in alignment with the international service standards. In brief, the nurse-to-patient ratio in medical-surgical units is recommended to be 1:4-1:6 in daytime. More nurses should be assigned to critically ill patients (1:2) and pediatric patients (1:4). Please refer to Table 16 (pp. 49) for the recommended ratios in details. The recommended ratios may be modified when new evidence emerges.

In view of the current low staffing ratios in Hong Kong, the projection of nursing requirement should aim to improve nurse-patient ratio with a transparent algorithm. A surveillance system to capture the unit-level nurse staffing data and patient outcomes should be established. The information will provide valuable information in determining the safe staffing level.

1. Background

The World Health Organization (WHO) estimated that the WHO regions experienced a shortage of 2.4 million doctors, nurses and midwives and 1.9 million other health workers.[1] Africa and South-east Asia are the regions with the most critical shortages of health workers. Although the developed countries are relatively less affected by many poverty-linked diseases, their health care needs are surging. Owing to the aging population, the health care workers are facing an increasing burden of chronic and degenerative diseases that require intensive and long-term care. With higher income, these countries require a larger workforce to provide basic health care to their populations. Additional demands for health workers also come from preventive care, service specialization and new infectious threats.

Workforce management is an indispensable part of the planning of nursing and midwifery services. WHO proposed a working lifespan approach to workforce management that covers three stages: "entry", "workforce", and "exit".[1] The "entry" stage aims to train sufficient numbers of qualified health workers with appropriate skills to meet the diverse needs. The "workforce" stage aims to enhance the performance by effective supervision, reliable compensation, adequate system supports, and opportunities for continuing education. The "exit" stage aims to plan ahead for workforce migration and retirement as well as reduction of unnecessary attrition. WHO has recently laid out the 5-year strategic directions for nursing and midwifery services.[2] One of the five proposed key results areas is workforce management with primary focuses on the provision of equitable access to services and fostering a positive work environment. WHO also added that workforce planning should follow evidence-based recommendations as far as possible.

1.1. The Hong Kong experience

The Hospital Authority is a statutory body responsible for providing public health care in Hong Kong. Serving approximately 7 million residents in Hong Kong, the Hospital Authority provides subsidized preventive, curative and rehabilitative services through 41 public hospitals and institutions, 47 specialist out-patient clinics, and 74 general out-patient clinics. In Year 2011/12, the f received a financial provision of over HK$36 billion from the government.[3] There are 21,072 nurses

working with the Hospital Authority, constituting 35% of its entire workforce and 51% of the total licensed nurses (the others are either working in the private sector or inactive).[3]

The number of licensed nurses per 1,000 population was 5.6 in 2010,[4] which was lower than that in many developed countries. The number in many developed countries exceeded 10 per 1,000 population (United States, Canada, Switzerland, Sweden, Germany, Netherlands, New Zealand, and Australia) or even 20 per 1,000 population (Denmark, Finland, and Norway). Following the closure of hospital-based nursing schools (offering diploma courses for enrolled nurses) since 1999, the number of nursing graduates drastically shrank from 1,391 in 2001/02 to a few hundred in late 2000s (Table 1; pp.7). Owing to the severe undersupply of nurses, there was a significant expansion of diploma nursing programs for registered nurses and re-opening of training program for enrolled nurses in the subsequent years. About 1200 registered nurses and 645 enrolled nurses graduated in 2011/12. The total number of graduates is expected to rise to 2,310 in 2012/13 and 2,165 in 2013/14.[5,6]

Table 1. Number of nurse graduates (2001/02 – 2007/08) and projected supply of nurse graduates (2011/12 – 2013/14) in Hong Kong[5,6]

	Number of nurse graduates							Projected supply of nurse graduates		
	01/02	02/03	03/04	04/05	05/06	06/07	07/08	11/12	12/13	13/14
RNs	1268	416	358	336	516	567	597	1200	1415	1490
ENs	123	-	-	-	-	-	-	645	895	675
Total	1391	416	358	336	516	567	597	1845	2310	2165

ENs, enrolled nurses. RNs, registered nurses.

The effect of the increase in the supply of nurses has yet to be determined but the public hospitals are now facing an unprecedented rate of turnover. The Hospital Authority laid out three strategic intents regarding the workforce management in 2009: (1) better able to manage growing demand, (2) better service quality and safer services, and (3) nurture a skilled and high performing workforce (Hospital Authority's Annual Plan 2011-2012). It has also outlined a number of initiatives to attract and retain nurses mainly by offering better remuneration package, career prospects, and working environment. The effectiveness of these retention strategies was in doubt, which was reflected in the increased turnover rate,

low level of nurse-to-patient ratio and job satisfaction, and high level of work stress.

A discussion paper of the Hospital Authority highlighted that the turnover rate increased from 3.2% in 2006/07 to 5.4% in 2010/11.[7] The turnover rates in pediatrics and orthopedics & gynecology even reached 7% and 8.8% in 2010/11, respectively. The high-turnover rate is undoubtedly related to the overwhelming workload. According to a recent survey conducted by the Association of Hong Kong Nursing Staff (AHKNS),[8] the nurse-to-patient ratio as reported by 2,812 nurse respondents is 1:11 in morning shifts, 1:12 in afternoon shifts, and 1:24 in night shifts. The nurse-to-patient ratios are invariably different among hospital clusters. New Territories West Cluster has the lowest nurse-to-patient ratios with 1:13 in morning shifts, 1:14 in afternoon shifts, and 1:31 in night shifts. The survey also revealed that nurse respondents perceived a very high level of stress (mean score 7.4 out of 10) and a low level of job satisfaction (mean score 4.3 out of 10).[8] Another local study reported that nurses in Hong Kong perceived job demands as one of the major sources of work stress,[9] which is a consistent correlate of job dissatisfaction and burnout.[10,11] Nurses in Hong Kong are now experiencing unprecedented stress and amount of work. Although the Hospital Authority has taken initiatives to retain staff, the demands for safe staffing have not been fully answered. Patient safety may be put into risk.

1.2. Methods of staff planning

To determine the required size of the nursing workforce, several approaches have been proposed. In real clinical setting, hospital administrators may develop locally specific tools using a combination of more than one approach. Hurst[12] gave a detailed description of the methods for staff planning which can be summarized as below.

(1) Professional judgment method

This method is simple and workable with limited amount of information. A group of experts would have to decide how many nurses are required to provide care in each shift based on their professional judgment. Other variables in the formula included the duration of the rota cycle, work hours per shift, and a time-out multiplier. The time-out covers all paid or unpaid leave of absence. The unit of nurse staffing is Whole-time equivalent (WTE), which denotes the number of nurses required during the specified period. For example, to maintain a 5-day ward with 20 beds, the number of nurses required per shift is estimated as follows:

a. The experts estimated 4 nurses are staffed in all shifts (5 patients per nurse)

b. Assuming each nurse works for 44 hours per week

c. Total number of work hours: 8-hour morning shift * 4 nurses * 5 days + 8-hour evening shift * 4 nurses * 5 days + 10-hour night shift * 4 nurses * 5 days = 520 hours

d. Whole-time equivalents required for the ward: 520/44 = 11.8

e. Assuming each nurse takes 20% time-out allowance, the adjusted WTEs will be 11.8*1.2=14.2. In other words, 14.2 nurses are required to maintain the ward for five days.

This method can also be used to determine the number of nurses of each grade per shift if the number of funded WTEs is known. The intensity of staffing (number of nurses required per shift or total funded workforce) is determined by top-down processes. Hospital administrators can easily perform the staff planning by putting the local values in the formula. Time-out multiplier can be ascertained through the personnel database. This method would be more realistic if financial constraints and nursing shortage limit the size of the workforce. However, the top-down decisions may not necessarily take quality of care into account. The method is not sensitive to patient dependency change within the unit.

(2) Number of nurses per occupied bed

The required number of nurses of each grade is determined for each occupied bed instead of each ward.

a. One occupied bed requires 0.5 WTE registered nurse and 0.5 WTE enrolled nurse (total 1.0 WTE nurse).

b. A ward of 20 occupied beds requires 20 WTE nurses (20*1.0) on the duty rota.

A time-out multiplier (not shown above) should also be included in the formula. This approach is simple once the WTE nurses per occupied bed are known. Substantial data may be required to determine a reliable estimate of WTE nurses in each grade. Although more nurses can be assigned to units with higher patient acuity, this method is not sensitive to patient dependency change within the unit. It is less applicable to units with a small number of beds as the number of nurses required may be below 1.

(3) Acuity-quality method

This approach is designed to determine the staffing level in each dependency category. More nurses should be staffed if patient dependency is high. This method allows different levels of staffing to be assigned to different patient categories within a unit. The direct nursing time per day for each patient category is estimated. The total direct nursing hours are then calculated by multiplying the direct nursing time with the number of patients. A workload index, or acuity, is generated using these parameters (see example in Table 2; pp. 10).

Table 2. Nursing hours required using the acuity-quality method

	Category 1	Category 2	Category 3
Average number of patients	8	7	5
Average direct care time to each dependency category per day	50 minutes	110 minutes	250 minutes
Amount of direct care time relative to category 1	50/50=1	110/50=2.2	250/50=5
Workload index (number of patients*care time multiplier)	8*1=8	7*2.2=15.40	5*5=25
Direct care time for all patients in the category	8*50=400 minutes	15.4*50=770 minutes	25*50=1,250 minutes

As illustrated in Table 2 (pp. 10), the total direct care time for all patients per day is 40 hours 20 minutes. Assuming nurses assign 35% of their time for indirect care, the total working hours for 20 patients per every 5 days will be 310 hours (40.3/(1-0.35)*5). Multiplying the total hours with the time-out allowance (20%), the total hours will be 372. Assuming each nurse works 44 hours per week, the WTE nurses for a 5-day ward will be 8.5 (372/44).

(4) Activity-based method

When patient dependency is not a good indicator of nursing time required, the activity-based method may be applied. The size of the nursing team is determined according to the amount of nursing intervention performed. Nursing time for each intervention for each patient is estimated. The amount of nursing time required for each patient can thus be estimated. This method is more applicable to units with detailed records of individual care plan and where nursing interventions can be reasonably predicted. Again, the size of the nursing team can be determined together with the consideration of time-out and

hours for indirect care and break. Following this approach, commercial software packages such as GRASP® and TrendCare® are available for manpower planning.[13] For example, the workload measures of the GRASP® system include both direct patient care and indirect care.[14] The former includes evaluative processes (e.g. formulating and coordinating care), teaching and emotional support to patients and families, and direct care (e.g. bathing and feeding). The latter includes supporting work such as making phone calls and ordering supplies.

(5) Regression analysis method

This approach makes use of statistical method to estimate the size of the nursing establishment (dependent variable) as a function of a list of predictor variables, ie, bed occupancy rate. Miranda[15] simplified the Therapeutic Intervention Scoring System and generated 9 factors contributing to a composite nursing manpower use score in intensive care units (ICUs) by using multivariate regression techniques. These factors are basic monitoring, intravenous medication, mechanical ventilator support, supplementary ventilator care, single vasoactive medication, multiple vasoactive medication, dialysis techniques, specific interventions in the ICU, and specific interventions outside the ICU.

1.3. Towards safer staffing

While the greater call for safe staffing is beyond doubt, the debate continues on how to determine the level of safe staffing. Minimum nurse-to-patient ratio is one of the proposed strategies to resolve the argument.[16] Proponents argue that the ratios would improve quality of care and nurses' job satisfaction. The view has been supported by preliminary evidence suggesting that higher intensity of nursing care is associated with fewer patient adverse events.[17] Yet, some healthcare workers cast doubt on whether a fixed number would safeguard the quality of care in dynamic clinical settings and would be uniformly applied to hospitals with different organizational characteristics.[18] Other common arguments against minimum nurse-to-patient ratios are that: (1) the minimum ratios would be taken as the average or maximum ratios by hospital administrators, (2) registered nurses may be replaced by less costly assistive staff in order to meet the ratios, and (3) the minimum ratios did not take patient acuity into consideration.[19] The determination of minimum nurse-to-patient ratios is highly challenging. The ethical issues may prevent the use of a randomized controlled trial to determine the minimum

nurse-to-patient ratios (see Section 2.3 for details; pp. 23).

The present review systematically evaluated available literature about nurse-to-patient ratios in the hope of gaining further insights into this controversial issue. Overseas regulations or service standards with regard to safe nurse-to-patient ratios are summarized in the next section of this report. Chapter 3 (pp. 26) examines the relationship between nurse-to-patient ratios and patient outcomes using meta-analytic techniques. Chapter 4 (pp. 53) explores the role of supervisory nurses in safeguarding quality of care. Chapter 5 (pp. 56) outlines some recommendations on nurse staffing in Hong Kong, and the last section is the conclusion.

2. The mandated and recommended minimum nurse-to-patient ratios around the world

Chapter 2 is comprised of two major sections. The first section (pp. 13) summarizes the minimum nurse-to-patient ratio regulations in different regions of the world. The second section (pp. 16) summarizes the service standards or safe nurse-to-patient ratios as recommended by various overseas official or professional bodies. The recommended ratios may be set according to the levels of patient dependency, representing the service standards based on professional judgment. A range of factors may be considered in determining the ratios, such as patient dependency, quality of care, nurses' job satisfaction and burnout, nurse turnover rate, and hospital geographical settings.

2.1. The mandated nurse-to-patient ratios in different regions of the world

2.1.1. California, the United States

The legislation to mandate minimum nurse-to-patient ratio was a lengthy process. Despite the intense lobbying initiated by the California Nurse Association and other unions since 1993, the Assembly Bill 394 was not signed until 1999 and was put into full effect in 2004.[20]

The calculation of nurse staffing included only licensed nurses comprising registered nurses and licensed vocational nurses. The proportion of registered nurses among all licensed nurses in a unit should be 50% or above. The mandated nurse-to-patient ratios in different specialties as illustrated in Table 3 (pp. 14) represented the minimum staffing levels.[21]

Table 3. The California mandated nurse-to-patient ratios by specialty[20,22]

Specialty	Nurse-to-patient ratio
Medical-surgical	1:5
Intensive/critical care	1:2
Pediatrics	1:4
Labor and delivery	1:2
Antepartum	1:4
Postpartum couplets	1:4
Postpartum women only	1:6
Operating room	1:1
Post-anesthesia recovery	1:2
Psychiatric	1:6
Oncology	1:4
Step down	1:3
Telemetry	1:4
Emergency room	1:4
ICU patients in the emergency room	1:2
Trauma patients in the emergency room	1:1
Other specialty care	1:4

ICU, intensive care unit.

2.1.2. Victoria, Australia

In Victoria, Australia, the dispute over minimum nurse-to-patient ratio originated from the introduction of extreme fiscal measures on the health care system by the state government in early 1990s.[23] Two thousand nursing positions were cut and some were replaced by assistive and agency staff. Using a new funding model, hospitals received lower funding for the same level of care delivered. By the late 1990s, there were only 4.1 nurses to every 1,000 Australian people. The number of beds was reduced and the average length of stay was shortened. The staffing level was so low that provision of safe nursing care was seriously compromised.[24]

Supported by the majority of the Victorian nurses, the Victorian Branch of the Australian Nursing Federation (ANF) formally filed a demand for mandated nurse-to-patient ratios in 2000 with the Victorian Department of Human Services (VDHS). Negotiations with the VDHS and the Victorian Hospitals Industrial Association were so intense that the Victoria ANF mobilized nurses to go on collective industrial action. The dispute was finally taken over by the Australian Industrial Relations Commissions, a tribunal with powers over the institution of labor law. Decision to implement minimum nurse-to-patient ratios was finally reached in 2001 (Table 4; pp. 15). In 2004, minimum staffing ratio was revised from the patient-level (1:4) to the unit-level (5:20), allowing more flexible changes

in the intensity of nursing care in response to changes in patient acuity within the unit.[23,24]

Table 4. The Victoria mandated nurse-to-patient ratios[24]

	AM shift	PM shift	Night shift
General medical/surgical wards			
Level 1 hospital†	1:4 + in charge	1:4 + in charge	1:8
Level 2 hospital†	1:4 + in charge	1:5 + in charge	1:8
Level 3 hospital†	1:5 + in charge	1:6 + in charge	1:10
Level 3a hospital†	1:6 + in charge	1:6 + in charge	1:10
Other hospitals	1:6 + in charge	1:7 + in charge	1:10
All aged care wards	1:7 + in charge	1:8 + in charge	1:15
Acute wards	1:6 + in charge	1:7 + in charge	1:10
Ante-Postnatal wards	1:5 + in charge	1:6 + in charge	1:8
Delivery suites level 1,2, and 3	2 midwives to 3 delivery suites		
Neonatal intensive care unit	1:2 + in charge	1:2 + in charge	1:2 + in charge
Discrete level 2 special care units	1:3 (≥ 10 cots) 1:4 (<10 cots)	1:3 (≥ 10 cots) 1:4 (<10 cots)	1:3 (≥ 10 cots) 1:4 (<10 cots)
Accident and emergency			
Group 1	1:3 + in charge + triage	1:3 + in charge + triage	1:3 + in charge + triage
Group 2 (hospitals not in group 1 and with >5,000 presentations per annum)	1:3 + in charge	1:3 + in charge	1:3 + in charge
Group 3 (<5,000 presentations per annum)	Two division 2 nurses plus one floater (division 1 or division 2)		
Designated coronary care unit	1:2 + in charge	1:2 + in charge	1:3
High dependency unit	1:2 + in charge	1:2 + in charge	1:2
Palliative care	1:4 + in charge	1:5 + in charge	1:8
Rehabilitation unit			
Category 1 rehabilitation (amputees, acquired brain injury, spinal injury)	1:5 + in charge	1:5 + in charge	1:10
Category 2 rehabilitation	1:5 + in charge	1:7 + in charge	1:10
Geriatric evaluation management beds	1:5 + in charge	1:6 + in charge	1:10
Operating theatre	One scrub nurse, one scout nurse, and one anesthesia nurse		
Post-anesthetic care unit / recovery room			
Unconscious patients	1:1	1:1	1:1

†Level of the hospitals was determined by the teaching status and size. Level 1 hospitals are mainly leading teaching, research, and referral hospitals. Level 2 hospitals are large metropolitan and country base hospitals. Level 3 and level 3a hospitals are small to medium hospitals.

2.1.3. New South Wales, Australia

New South Wales of Australia is the third region to set up minimum nurse-to-patient ratio regulation. Minimum staffing ratios were applied only in medical-surgical wards, palliative care, rehabilitation, and acute adult inpatient mental health (Table 5; pp. 16).

Table 5. The New South Wales mandated nurse-to-patient ratios[25]

General medical/surgical wards	AM shift	PM shift	Night shift
Principal referral hospitals	1:4	1:4 + in charge	1:7
Major metropolitan and major non-metropolitan hospitals	1:4	1:5 + in charge	1:7
District group hospitals	1:5	1:5 + in charge	1:7
Community acute hospitals	Not available		
Palliative care units	1:4	1:4 + in charge	1:7
Inpatient mental health			
Acute adult in general hospitals	1:4	1:4 + in charge	1:7
Acute adult in specialist mental health facilities	1:4	1:5 + in charge	1:7
Rehabilitation			
Specialist brain and spinal injury units	1:4	1:4 + in charge	1:7
General rehabilitation units	1:4	1:5 + in charge	1:7

2.2. Clinical guidelines for safe nurse staffing by specialty

2.2.1. Adult intensive care

Following the global development of the specialty of intensive care since 1950s, British Medical Association (1967) pioneered in setting the gold standard for nurse staffing at a ratio of one nurse to one patient.[16] Department of Health of the United Kingdom (1996) supported the minimum nurse-to-patient ratio at 1:1 in all shifts at all time, but it also acknowledged that additional nurses should be arranged in accordance with patient needs, the total number of beds and geographical arrangements within the unit.[26] The Audit Commission of the United Kingdom (1999) recommended that staffing levels should match the actual workload required and the dependency needs of patients instead of deploying a rigid 1:1 nurse-to-patient ratio in the unit.[27] The most recently updated position statement in the United Kingdom was jointly contributed by the British Association of Critical Care Nurses (BACCN), Critical Care Networks National Leads Group (CC3N), and

Royal College of Nursing (RCN).[28] The position statement recommended that:

- Ventilated patients should have a minimum of one nurse to one patient.
- The nurse-to-patient ratio within any critical care unit should not go below one nurse to two patients.

According to the statement, the nursing team in a critical unit may include registered nurses, non-registered nurses, and other specialized nurses. However, every patient must be able to reach a registered nurse with a post-registration qualification in critical care directly.

Staffing ratios recommended by the British Columbia Nurses' Union (BCNU) are consistent with those recommended by BACCN, CC3N, and RCN. A minimum of one nurse is required to provide care to two patients or one ventilated patient at all times.

2.2.2. Neonatal care

The nurse-infant ratios forwarded by the British Association of Perinatal Medicine (BAPM) in 2001 were 1:1 in intensive care units, 1:2 in high dependency units, and 1:4 in special care units.[29] BAPM subsequently acknowledged that neonatal care required specialized skills that registered nurses or midwives may not possess. In 2010, BAPM further refined the staffing standards by specifying the qualification requirement for nurses without changing the staffing ratios.[30] Intensive care and high dependency care required a higher level of inputs from specialist nurses. As seen in Table 6 (pp. 18), Department of Health, the United Kingdom recommended the same staffing ratios as BAPM but with slight difference in skill mix requirement.

According to the position statement issued by the National Association of Neonatal Nurses (NANN) in 2008,[31] a minimum of two registered nurses with experience or training in neonatal care should be staffed in a unit of six immediate newborn babies or four intensive care newborn babies. NANN further recommended that a minimum of two registered nurses should be immediately available in case of emergency.

BCNU proposed that the minimum nurse-to-patient ratio should be 1:1 in neonatal intensive care unit.[32] Requirements for specialist experience and qualification of the workforce establishment were not described.

Table 6. BAPM and DoH service standards

Neonatal units	BAPM (2001)[29]	DoH, UK (2009)[33]		BAPM (2010)[30]	
	Patient per nurse	Patient per nurse	Skill-mix	Patient per nurse	Skill-mix
Intensive care	1	1	Cared by a nurse who has completed accredited specialized neonatal care training. ≥80% of the workforce are registered nurses.	1	Cared by a QIS nurse.
High dependency care	2	2	Cared by a nurse who has completed accredited specialized neonatal care training. ≥80% of the workforce are registered nurses.	2	Cared by a QIS nurse or by a registered nurse who is under the direct supervision of a QIS nurse.
Special care	4	4	Cared by a registered or non-registered clinical staff under the direct supervision of a QIS nurse. ≥70% of the workforce are registered nurses.	4	Cared by a registered or non-registered clinical staff under the direct supervision of a QIS nurse.

BAPM, British Association of Perinatal Medicine. DoH, UK, Department of Health, the United Kingdom. QIS, Qualified in Specialty.

2.2.3. General pediatric care

It is generally accepted that children's service demands greater intensity of nursing care. The general principle was that staffing levels in a children's ward should be higher than those in a comparable adult unit. RCN which published guidance for defining staffing levels for children's and young people's care indicated that the minimum nurse-to-patient ratios in general children's wards and departments were determined with reference to children's age and duty shifts:[34]

- Number of children aged under 2 years per registered nurse: 3
- Number of children aged >2 years per registered nurse during day shifts: 4
- Number of children aged >2 years per registered nurse during night shifts: 5

The nursing establishment in such a general setting should be composed of a minimum of 70% of registered nurses with a qualification in nursing care for children and young people.

BCNU's ratio guidelines were set out based on the sub-specialty of pediatric care. The minimum nurse-to-patient ratio in a general pediatric unit was 1:4, whereas the ratios in a pediatric oncology unit and a pediatric surgery unit were 1:2 and 1:3, respectively.[32]

2.2.4. Intensive pediatric care

Nursing standards for intensive care for critically ill children in the United Kingdom were initially set out by the Department of Health in 1997.[35] The initial registered nurse to patient ratio was 1:1 in Level 2 or 3 care (intensive care) at the bedside at all times. Two registered nurses may be needed to provide safe care to children with the highest level of intensive supervision. The Paediatric Intensive Care Society (PICS) recently revised the minimum staffing ratios by level of care:[36]

- Level 1 (high dependency care): one registered nurse to two patients
- Level 2 (unstable non-intubated child or child requires advanced respiratory support): one registered nurse to one patient
- Level 3 (child requires intensive supervision at all times or nursed in a cubicle): 1.5 registered nurses to one patient
- Level 4 (child requires the highest level of intensive supervision at all times or child undergoing renal replacement therapy): two registered nurses to one patient

2.2.5. Midwifery/Obstetric care

The minimum standards for labor and delivery in the United Kingdom are jointly contributed by the Royal College of Obstetricians and Gynaecologists (RCOG), Royal College of Midwives (RCMW), Royal College of Anaesthetists (RCA), and Royal College of Paediatrics and Child Health (RCPCH).[37] To provide adequate and safe care to women in labor, the standard of 1:1 is adopted. The number of WTE midwife required to provide one-to-one care in labor increases with the degree of case complexity (Table 7; pp. 20).

Table 7. Minimum staffing standards forwarded by RCOG, RCMW, RCA, and RCPCH[37]

Level of risk	Number of WTE midwife per woman required in order to deliver the standard one-to-one care in labor
Low risk	1 WTE midwife to 1 woman
Moderate risk	1.2 WTE midwife to 1 woman
Higher risk	1.3 WTE midwife to 1 woman
Highest risk	1.4 WTE midwife to 1 woman

WTE, whole-time equivalent (hours worked divided by the contracted hours)
RCOG, Royal College of Obstetricians and Gynaecologists. RCMW, Royal College of Midwives. RCA, Royal College of Anaesthetists. RCPCH, Royal College of Paediatrics and Child Health.

BCNU proposed a minimum nurse-woman ratio of 1:4 for antepartum care and of 1:1 for labor and delivery.[32]

2.2.6. Adult psychiatric care

Existing staffing standards for psychiatric care is lacking partly because of the difficulty in quantifying nursing workload as well as the lack of studies examining the relationship between staffing ratios and patient outcomes. Instead of setting out service standard for adult psychiatric in-patient care, Royal College of Psychiatrists (RCP) commented that a group of 15 patients in an acute adult ward would unlikely be safely managed with three registered nurses (1998). Otherwise, no other guideline was identified with regard to safe staffing in an acute adult ward.

2.2.7. Child and adolescent psychiatric care

The American Academy of Child and Adolescent Psychiatry (AACAP) and RCP issued their own guidelines on nurse staffing ratios, which were determined by the nature of shift activities and case dependency (Table 8; pp. 21). AACAP required only one registered nurse to provide care to 12 patients per shift.[38] RCP required that a minimum of two experienced registered nurses during the day or one during the night should be on duty per shift.[39] The position statement of American Psychiatric Nurses Association (APNA) did not establish any standard staffing ratios for in-patient psychiatric care.[40] APNA noted that staffing level is a function of multiple factors such as case mix, nursing skill mix and education, physical environment, etc. It also stated that developing staffing plans was an ongoing process that required a transparent method of evaluation. Quality indicators such as patient outcomes and staff satisfaction should be included in the evaluation of

staffing plans.

Table 8. Nurse staffing recommendation in child and adolescent psychiatric units

	AACAP (1990)	RCP (1999)	
		Low dependency	High dependency
Night-time	Minimum 2 staff (plus an additional on-call staff)	Minimum 2 staff (plus an additional on-call staff)	1:3
Basic observation and maintenance of safety	1:3	1:3 to 1:4	1:2 to 1:3
Active milieu therapy during day and evening	1:2 or 4:6	1:3	1:2
Emergency/intensive care	-	1:2	1:1

AACAP, American Academy of Child and Adolescent Psychiatry. RCP, Royal College of Psychiatrists.

2.2.8. Post-anesthesia recovery

BCNU recommended that the minimum staffing standard for post-anesthesia recovery was one nurse to every two conscious patients or one nurse to one unconscious patient at all times. Staffing ratios can be increased in consideration of patient acuity and other factors.[32] Recommendations of safe staffing levels for children in the post-anesthesia period were available from the American Society of PeriAnesthesia Nurses (ASPAN).[41] The standard staffing levels were established according to the phase of care. Generally, one perianethesia registered nurse was allowed to provide care to two patients during Phase I (immediate post-anesthesia period) level of care. A higher nurse-to-patient ratio at 1:1 would be needed when the patient was at the time of admission until being considered as stable by the care provider, had an unstable airway, or aged 8 years or under. A nurse-to-patient ratio at 2:1 would be needed for critically ill and unstable patients.

Phase II (preparing for home care or extended level of care) level of care allowed a lower nurse-to-patient ratio at 1:3. A higher staffing ratio was required for patients aged 8 years or less without the presence of family or support staff (1:2), initial admission of patients who are considered to be stable (1:2), or unstable patients of any age requiring transfer (1:1). The unit or room had two nursing personnel, one of whom should be a registered nurse with experience in Phase II perianesthesia care, when a patient was present. If the patient required extended care after Phase II, the nurse-to-patient ratio may be further lowered from 1:3 to 1:5.

Table 9. Summary of mandated and recommended nurse-to-patient ratios by specialty (only nurses who provided direct care were included)

	Work shift	Specialty											
		Medical-surgical	Oncology	Adult intensive	Child intensive	Neonatal care	General pediatrics	Obstetrics/Midwifery			Adult psychiatric	Child & adolescent psychiatric	Post-anesthesia recovery
								Ante-partum	Labor & delivery	Post- partum			
California[20,22]		1:5	1:4	1:2			1:4	1:4	1:2	1:4-1:6*	1:6		1:2
Victoria[24]	AM	1:4-1:6†		1:2‡	1:2			1:5	2 midwives to 3 delivery suites	1:5			1:1 (un-conscious patients)
	PM	1:4-1:7†		1:2‡	1:2			1:6		1:6			
	Night	1:8-1:10†		1:2‡	1:2			1:8		1:8			
New South Wales[25]	AM	1:4-1:5†									1:4		
	PM	1:4-1:5†									1:4-1:5§		
	Night	1:7									1:7		
BCNU[32]		1:4		1:1-1:2¶	1:1		1:4	1:4	1:1				1:1-1:2**
BACCN, CC3N, RCN[28,42]				1:1-1:2¶									
BMA (1967)[16]				1:1									
DoH, UK (1996)[26]				1:1									
BAPM [29,30]						1:1-1:2††							
DoH, UK (2009)[33]						1:1-1:2††							
NANN[43]						1:2							
RCN[34]							1:3-1:5‡‡						
PICS[36]					2:1-1:1§§								
RCOG, RCMW, RCA,& RCPCH[37]									1:1				
RCP[39]											> 3:15	1:1-1:4§§	
AACAP[44]												1:2-1:3§§	
ASPAN[41]													2:1-1:3¶¶

* 1:4 for postpartum couplets and 1:6 for postpartum women only.
† Minimum nurse-to-patient ratio was determined by the sizes of hospitals.
‡ High dependency unit.
§ 1:4 in general hospitals; 1:5 in specialist mental health facilities.
¶ A minimum of one nurse is required to provide care to two patients or one ventilated patient.
** 1:2 for conscious patients; 1:1 for unconscious patients.
†† 1:1 in intensive care units; 1:2 in high dependency units.
‡‡ Nurse-to-patient ratio was determined by children's age and work shifts.
§§ Nurse-to-patient ratio was determined by the patient dependency levels.
¶¶ Nurse-to-patient ratio was determined by the phase of care.

BCNU, British Columbia Nurses' Union. BACCN, British Association of Critical Care Nurses. CC3N, Critical Care Networks National Leads Group. RCN, Royal College of Nursing. BMA, British Medical Association DoH UK, Department of Health, the United Kingdom. BAPM, British Association of Perinatal Medicine. NANN, National Association of Neonatal Nurses. RCN, Royal College of Nursing. PICS, Paediatric Intensive Care Society. RCOG, Royal College of Obstetricians and Gynaecologists. RCMW, Royal College of Midwives. RCA, Royal College of Anaesthetists. RCPCH, Royal College of Paediatrics and Child Health. RCP, Royal College of Psychiatrists. AACAP, American Academy of Child and Adolescent Psychiatry. ASPAN, American Society of PeriAnesthesia Nurses.

2.3. Safe staffing level in terms of nurse-to-patient ratio

Nurse-to-patient ratio is one among many other nurse staffing variables that may influence patient outcomes. The use of nurse-to-patient ratio as the major staff planning tool has been supported by various international guidelines (Table 9; pp. 22). Compared with other staffing measures, nurse-to-patient ratio is favored because of its administrative convenience. Hospital administers and frontline nurses can monitor the implementation at a lower cost. To justify the implementation of safe ratios, another key issue is to demonstrate that improved ratios reduce adverse patient outcomes.

Aiken surveyed 22,336 hospital nurses in California, Pennsylvania, and New Jersey, where the latter two states did not have mandated nurse-to-patient ratios.[44] Average nurse-to-patient ratios for all staff nurses in the three states were 1:4.1, 1:5.4, and 1:5.4, respectively. The average nurse-to-patient ratios in California were the lowest compared with the other two states. According to the study, the average staffing ratio decreased from 1:5.08 in 2000-2002 to 1:4.08 in 2005-2006. Average work hours by registered nurses, licensed vocational nurses, and nurse aides increased within the same period. The proportional increase was greater for registered nurses (42%) than for licensed vocational nurses (9%) and nurse aides (8%). Hospitals with initially lower nurse-to-patient ratios had the greater proportional increase in work hours by registered nurses.

A few studies have been conducted to examine whether better quality of care was succeeded by the minimum ratio regulation. A study[46] reported that California hospitals with the lowest staffing level had significantly lower failure-to-rescue rates (coefficient=-30.7%; S.E.=14.1) than comparison hospitals in other states without minimum staffing legislation. However, another Californian study[47] did not find an improved failure-to-rescue rate with improved nurse-to-patient ratios. The preliminary findings suggested that hospitals with lower nurse staffing before the legislation showed greater increment in staffing as well as fewer adverse events after the legislation. No findings have yet been published to address the impacts of minimum staffing ratios on patient outcomes in Victoria and New South Wales.

The determination of the effectiveness of minimum ratio regulation is complicated by ethical issues. To rigorously determine the safe staffing level, hospitals may opt to randomize patients into groups with different staffing levels. However, the existing code of practice likely prevents a simple random sampling (the sampling process is purely by chance). It is widely accepted that patient with higher acuity should receive greater intensity of nursing care. Randomizing patients with

different levels of acuity may breach the service standards. The development of a trial is further complicated by the problem of exercising individual randomization because nurse staffing is inherently clustered by unit instead of individual patients. The territory-wide nature of the nurse-to-patient ratio regulation also precludes the possibility of a concurrent control group. A lot of resources are required to plan a cluster randomized trial with stratification of patient dependency. These methodological challenges would explain why only very few interventional studies were conducted to examine the effectiveness of minimum ratio regulation.

Due to the methodological challenges as outlined above, observational studies which investigate the relationship between nurse-to-patient ratios and patient outcomes become the major source of empirical evidence. Results from these observational studies provide the best available evidence and shed insight on the use of nurse-to-patient ratio in manpower planning and service evaluation.

2.4. Nurse-to-patient ratios and patient dependency

It is recognized that a fixed nurse-to-patient ratio alone may not be accurate enough to address the differential needs arising from patient acuity. The recommended safe nurse staffing levels as listed above were either supplemented by a patient classification system or set according to the level of dependency. The main purpose of categorizing patients is to determine their needs, to estimate workload, and to effectively allocate adequate number of staff with sufficient skills to meet their needs.[48] In California, the patient classification system existed in parallel to the minimum ratios. Whenever the patient classification system showed that a higher staffing ratio was needed, hospital administrators were obligated to assign more nurses to meet the patient needs.[20] Apart from the locally developed patient classification systems, there are a few commonly used systems such as GRASP® and Medicus (For details, please refer to Section 1.2 acuity-quality methods; pp. 10).[49] California Code of Regulations requires the hospitals to establish a valid and testable patient classification system for predicting nursing requirements of individual patients. Staff resources will be allocated according to the estimated nursing requirements. Gerdtz[50] considered that the patient classification system would be more appropriate to predict the short-term staffing needs. But she also pointed out that many patient classification systems consistently underestimated the time required for care. The patient classification system may also encourage the use of agency staff to meet the changing service needs. Adomat[48] argued that patient classification systems were sensitive to patient morbidity and mortality, but not reliable for determining the safe staffing level. She also pointed out that patient acuity might not always reflect the

amount of nursing hours required. For example, an unconscious, immobile patient may require less nursing time than a recovering patient who is able to verbalize his/her needs.

To date, the debate on how patient should be classified and how workload should be objectively measured is still inconclusive. The effectiveness of determining safe nurse-to-patient ratios on the basis of patient classification systems should be further investigated.

3. Review of nurse-to-patient ratios and patient outcomes

3.1. Safety in numbers

Preliminary evidence as suggested by a number of systematic reviews supported an inverse relationship between intensity of nursing care and a range of patient adverse events such as mortality, failure to rescue, length of stay, healthcare-associated infections, post-operative complications, urinary tract infections, pressure ulcers, and patient falls.[51-56] However, these findings were concluded based on studies using a wide range of nurse staffing measures. The use of nurse-to-patient ratios would not be supported unless a clear and consistent relationship between nurse-to-patient ratios and patient outcomes could be demonstrated. Most of the published reviews did not incorporate a meta-analysis, making the impacts of nurse staffing less definite. The infrequent use of meta-analysis was partly explained by the paucity of studies and the large variations in nurse staffing measures. A recent review by Kane[57] reported that one additional registered nurse full-time equivalent (FTE) per patient day was associated with 9%-16% lower odds of hospital-related mortality. The review included multiple reports from the same cohorts in the meta-analysis; hence the confidence interval of the pooled estimate would be biased towards one direction.

Nurse staffing variables are likely implicated in the delivery of quality of care, but it is unclear whether the number of nursing staff matters. Nursing hours per patient day and total nursing hours are commonly used nurse staffing measures. However, nursing hours may not be the best method to quantify intensity of nursing care because this measure may include both direct and indirect nursing care hours. Nurse-to-patient ratio, among many other nurse staffing measures, is simple to be interpreted and executed. Some argued that nurse-to-patient ratio was an inadequate measure because the measure only put number of nurses into consideration. Hospital administrators may manipulate the ratios by replacing registered nurses with less experienced workers. It is thus important to include skill-mix indicators such as registered nurse-to-patient ratios and percentage of registered nurse staffing in the evaluation of the quality of nursing care.

In view of the above arguments, this review summarized all published literature on the relationship between nurse-to-patient ratios and patient outcomes. The present review was different from the previous reviews[51-56] in that nurse-to-patient ratio was the only staffing measure of interest. The primary objective was to assess and quantify the effects of nurse-to-patient ratios on patient outcomes. The

outcomes of interest were selected due to their potential indication of quality of care. Specific review questions were developed as follows:

1. Is nurse-to-patient ratio, in particular registered nurse to patient ratio, associated with patient mortality?
2. Is nurse-to-patient ratio, in particular registered nurse to patient ratio, associated with patient length of stay?
3. Is nurse-to-patient ratio, in particular registered nurse to patient ratio, associated with medication errors?
4. Is nurse-to-patient ratio, in particular registered nurse to patient ratio, associated with a range of nurse-sensitive patient outcomes: failure to rescue, pneumonia, urinary tract infection, nosocomial infections, pressure ulcer, patient fall, pulmonary insufficiency/failure, unplanned extubation, and Methicillin-resistant staphylococcus aureus acquisition.

3.2. Search strategy

Potential studies were identified in major electronic databases, including Medline, Embase, Cumulative Index to Nursing and Allied Health Literature Plus, PsycINFO, Global Health, Education Resources Information Center, Academic Search Premier, British Nursing Index, and SCOPUS. Reference lists of the published reviews were also screened for eligible studies.

The search was performed on January 21st, 2013 and used a combination of keywords and free texts as follows: “nurses”, “nursing staff”, “nursing service, hospital”, “nursing administration research”, “nursing education research”, “nursing evaluation research”, “personnel management”, “personnel administration, hospital”, “personnel staffing and scheduling”, “health manpower”, “nurse staffing”, “nursing manpower”, “models, nursing”, “ratioing”, quality of health care”, “clinical competence”, “outcome and process assessment (health care)”, “outcome assessment (health care)”, “program evaluation”, “quality assurance, health care”, “mortality”, and “length of stay”. Eligible studies published from 1980 onwards were included in the review.

A study was considered eligible if it:

- was a prospective or retrospective cohort study, cross-sectional study, case-control study, or randomized controlled trial.
- used one of the following nurse staffing variables:[57]
  - Number of patients per nurse per shift

- Number of nurse FTEs per patient day or per occupied bed
- Number of nurse FTEs per 1,000 patient days

- explored relationship between nurse-to-patient ratio and pre-defined patient outcome and reported statistical estimate for the relationship.

Depending on the definition of individual studies, the calculation of nurse-to-patient ratio may include registered nurse, enrolled nurse or licensed practical (vocational) nurse, and sometimes nursing assistants. To summarize the characteristics and findings of individual studies, a structured data extraction form was developed for the review purpose (Appendix 1). Information including authors, year of publication, place, study design, sample size, specialty of interest, data source, method of analyses, nurse staffing measurements, outcomes and effect measures, and adjusted variables were summarized. Quality of the study was evaluated in terms of sample representativeness, quality of measurement, response rate, methods of analyses, adjustment for confounding factors, and presentation of results.

3.3. Nurse staffing measures

Definitions of nurse staffing measures varied from studies to studies. Majority of the studies (n = 28) expressed the staffing measure as either the number of patients per nurse per shift or number of nurses per patient per shift. Another 11 studies used number of nurse FTEs per patient day whereas the remaining 3 studies used number of nurse FTEs per 1,000 patient days. One FTE equals to one full-time worker who has fulfilled all contracted work hours. In other words, if the contracted hours for a full time nurse are 40 hours per week, a nurse who has worked 20 hours per week represents 0.5 FTE. Unless otherwise specified, a study was assumed to include all types of direct nursing staff in the calculation of nurse-to-patient ratio. Studies which used only registered nurse in the calculation were indicated in Table 12 (pp. 32). "Nurse-to-patient ratio" refers to the average number of patients taken care by a clinical nurse who may or may not be a registered nurse. "Registered nurse-to-patient ratio" refers to the average number of patients taken by a registered nurse.

In order to synthesize the study results, nurse-to-patient ratios were converted into two standardized measures as suggested by Kane:[57] number of patients cared for by one nurse per shift and nurse FTE per patient day. Conversion examples can be found in Table 10 (pp. 29).

To avoid confusion, staffing ratios will be described as follows. A

nurse-to-patient ratio of 1:5 denotes that a nurse takes care of 5 patients. A higher nurse-to-patient ratio (>1:5) means that a nurse takes care of less than 5 patients (e.g. 1:4). A lower ratio (<1:5) means that a nurse takes care of more than 5 patients (e.g. 1:6).

Table 10. Standardization of nurse staffing measures[57]

	Examples
If the number of nurse FTE per patient day was reported, the corresponding number of patients per nurse per shift would be: $= \frac{24 \text{ hours}}{Reported\ nurse\ hours\ per\ patient\ day}$ $= \frac{24\ hours}{Reported\ FTEs\ per\ patient\ day * 1\ nurse\ FTE\ per\ patient\ day\ (= 8\ hours)}$	FTE/patient day= 0.6 = 24 hours / (0.6 nurse FTE*8 hours) = 5 patients/nurse/shift
If the number of patients per nurse per shift was reported, the corresponding number of nurse FTE per patient day would be: $= \frac{Reported\ nurse\ hours\ per\ patient\ day}{8\ hours}$ $= \frac{\left(\frac{24\ hours}{number\ of\ patients\ assigned\ to\ a\ nurse\ per\ shift}\right)}{1\ nurse\ FTE\ hours\ per\ patient\ day}$	2 patients/nurse/shift = 24 hours/2 patients/8 hours = 1.5 nurse FTEs/patient day
If the number of patients per 1,000 patient days was reported, the corresponding number of patients per nurse per shift would be: $= \frac{24 \text{ hours}}{Reported\ nurse\ hours\ per\ patient\ day}$ $= \frac{24 \text{ hours}}{(Reported\ nurse\ FTEs\ per\ 1{,}000\ patient\ days * nursing\ hours\ per\ year)/1000}$	3.5 nurse FTEs/1,000 patient days = 24 hours/((3.5 FTEs/ 1,000 patient days*1,800 hours)/1,000) = 3.8 patients/nurse/shift

The calculation assumed that each shift lasted 8 hours and each nurse worked 37.5 hours per week and 48 weeks per year, totaling 1,800 hours per year.

3.4. Outcome measures

A dichotomous measure of mortality was commonly referred to either in-patient mortality or 30-day mortality (30-day outcome since admission). A continuous mortality outcome was often referred to mortality rate or standardized mortality ratio. The standardized mortality ratio was the ratio of the observed mortality to the expected mortality with respect to the average (hospital) population. Failure to rescue was defined as deaths caused by the development of complications. Length

of stay and medication errors were also evaluated. Other nurse-sensitive patient outcomes included pressure ulcers, pulmonary insufficiency/failure, nosocomial infections, unplanned extubation, patient falls, hospital-acquired pneumonia, hospital-acquired urinary tract infection, and methicillin-resistant staphylococcus aureus acquisition. Many of these nurse-sensitive outcomes are included in the nursing quality indicator provided by the Joint Commission[58] and the National Database of Nursing Quality Indicators.[59]

3.5. Data synthesis

The relationship between nurse-to-patient ratios and patient outcomes were systematically examined. Three groups of data synthesis were carried out. The first set of analysis pooled studies examining a binary outcome with a continuous nurse staffing measure. The pooled odds ratio (OR) was the effect of one unit increase in nurse FTE per patient day. The confidence interval of the pooled odds ratio crossing 1.0 indicated that there was no association between nurse staffing and patient outcome. The second set of analysis pooled studies examining a continuous outcome with a continuous nurse staffing measure. The pooled estimate represented the effect of one unit increase in patient per nurse per shift. The third set of analysis pooled studies examining a binary or continuous outcome with nurse-to-patient ratios in categorical groups (2 groups, 3 groups, or 4 groups). If nurse staffing group comparison of one study approximated to that of another study, the estimates were pooled. For example, if there were two studies examining the difference in standardized mortality ratio between nurse patient ratios at ≥1:2 and <1:2, the effect estimates were pooled. A subgroup analysis repeated the above procedure by only selecting studies using registered nurse-to-patient ratios.

To allow heterogeneity between studies, the random effect model was adopted. Heterogeneity statistics, I^2, were used to report the proportion of total statistical heterogeneity. A higher percentage (range 0-100) of I^2 indicated a higher level of statistical heterogeneity. RevMan 5.2 was used to perform the meta-analysis.

3.6. Results

3.6.1. Characteristics of included studies

A total of 2,546 references were identified from the search, where 93.6% of them were excluded after initial screening of titles and abstracts. Full-texts of 146 references were retrieved and the remaining 18 references were non-retrievable.

Among the 146 selected references, 51 were included in the meta-analysis. Reasons of exclusion of the excluded studies are reported in Table 11 (pp. 31).

The 51 references represented 42 studies (Table 12; pp.32), in which 6 were prospective cohort studies, 1 was prospective nested case-control study, 34 were retrospective cross-sectional studies, and 1 was cross-sectional case-control study. In terms of study place, 29 studies were from the United States, 4 studies from the United Kingdom, 2 studies from Taiwan, 1 study from Australia, 1 study from Brazil, 1 study from Canada, 1 study from China, 1 study from Kuwait, 1 study from South Korea, and 1 study from Thailand. Detailed characteristics of the selected studies were illustrated in Table 12 (pp. 32).

The calculation of nurse staffing level usually includes nurses who provide direct care. In other words, the calculation may include registered nurses, enrolled nurses or licensed practical (vocational) nurses, and sometimes nursing assistants. It has been criticized that nurse-to-patient ratio may not truly reflect the quality of nursing care if not taking skill mix into account. A significant proportion of the included studies (n = 23) focused on exploring the relationship between registered nurse-to-patient ratios and patient outcomes as registered nurses are expected to possess better skills and knowledge to provide quality nursing care. The primary analysis included studies using all types of direct nursing staff in the calculation of nurse-to-patient ratios. A subgroup analysis was also conducted to include studies using only registered nurse-to-patient ratio (Section 3.7; pp. 45).

Table 11. The excluded studies (n = 95)

Reasons of exclusion	No. of studies
Not using nurse-to-patient ratio as a staffing measure	50
Not studying pre-defined patient outcomes	15
Not using nurse-to-patient ratio as a staffing measure and not studying pre-defined patient outcomes	7
Comments or editorial	5
Cost analysis	3
Staffing-outcome relationship was not explored	3
Study was not intended to study staffing-outcome relationship	4
Statistical estimate for the staffing-outcome relationship was not provided	2
Review	2
Feature	1
Numerical value of nurse-to-patient ratio was not provided	1
Secondary report	1
Study design and rationale paper without study results	1

Table 12. Characteristics of the selected studies

Study	Place	Design	Specialty/ patient group	Sample	Nurse staffing measures	Results	Adjustment
Aiken (1999)[60]	US	Cross-sectional	AIDS units	1,205 patients	RN FTE/patient day	Mortality *OR*=0.46 (0.22, 0.98)	Hospital characteristics, patient characteristics, illness severity
Aiken (2002);[61] Aiken (2003); [62] Kutney-Lee (2008);[63] Silber (2000) [64]	US	Cross-sectional	Surgical	232,342 patients	RN-patient ratio; RN/bed ratio	Mortality *OR*=1.07 (1.03, 1.12) FTR *OR*=1.07 (1.02-1.11) LOS *% change*=1.0 (-1.0, 3.0)	Nurse, patient, and hospital characteristics
Aiken (2011);[65] Carthon (2012)[66]	US	Cross-sectional	Surgical	1,262,120 patients	RN-patient ratio	Mortality *OR*=1.039 (1.016, 1.063) FTR *OR*=1.039 (1.016-1.063)	Sex, age, transfer status, types of surgery, comorbidities, hospital characteristics
Alonso-Echanove (2003)[67]	US	Prospective cohort	Medical / surgical	4,535 patients	RN-patient ratio	n.s. association with bloodstream infection. Estimate not reported.	Total parenteral nutrition, antimicrobial-impregnated central venous catheter
Amaravadi (2000)[68]	US	Cross-sectional	ICU patients underwent esophageal resection	366 patients	Nurse-to-patient ratio	Mortality *OR*=0.7(0.3-2.0) LOS *% increase* = 39 (19-61) Respiratory pneumonia *OR*=2.4 (1.2-4.7) Post-operative infection *OR*=1.4 (0.5, 3.8)	Age, sex, race, type and nature of operation, admission type, hospital and surgeon volume
Bastos (1996)[69]	Brazil	Prospective cohort	ICU (medical / surgical)	1,734 patients	Nurse-to-patient ratio	Standardized mortality ratio *coefficient* = 0.32, n.s.	Technology availability, diagnostic diversity
Bond (1999)[70]	US	Cross-sectional	Medical / surgical	3,763 hospitals	RN-to-bed ratio	Mortality rate *coefficient*=-0.0026, *s.e.*=0.001	Severity of illness, hospital occupancy rate, teaching hospital status, ownership,

Study	Place	Design	Specialty/ patient group	Sample	Nurse staffing measures	Results	Adjustment
							other personnel to bed ratio
Callaghan (2003)[71]	Australia	Cross-sectional	ICU (pediatrics)	692 patients	Nurse-to-patient ratio	Mortality *OR*=0.18 (0.06, 0.5)	Clinical Risk Index for Babies, unit workload
Cho (2008)[72]	South Korea	Cross-sectional	ICU	27,372 patients	Average daily census/RN ratio	Mortality in tertiary hospitals *OR*=0.54 (0.22-1.33) Mortality in secondary hospitals *OR*=1.43(1.16-1.77)	Age, sex, health insurance, ICU and hospital characteristics
Cook (2012)[47]	US	Cross-sectional	Medical / surgical	294 hospitals	Nurse-to-patient ratio	Pre-regulation FTR rate *coefficient*=0.0030, *s.e.*=0.0017 Decubitus ulcer rate *coefficient* =0.0012, *s.e.*=0.0006 Post-regulation FTR rate *coefficient*=0.0037, *s.e.*=0.0021 Decubitus ulcer rate *coefficient*=-0.0027, *s.e.*=0.0008	Discharges, case-mix, skill-mix
Dang (2002);[73] Pronovost (1999);[74] Pronovost (2001)[75]	US	Cross-sectional	ICU (surgical)	2,987 hospitals	Nurse-to-patient ratio	Respiratory complications Medium NPR (vs high NPR) *OR*=1.03 (0.78, 1.38) Low NPR (vs high NPR) *OR*=2.33 (1.50, 3.60) n.s. association with mortality. No estimate provided LOS (NPR <1:2 vs >1:2) *% increase* =20 (7, 33) Pulmonary insufficiency (NPR <1:2 vs >1.2) *relative risk*=4.5 (2.9, 6.9)	Age, sex, race, severity of illness, comorbid diseases, hospital volume, ICU characteristics
Dimick (2001)[76]	US	Cross-sectional	ICU patients underwent hepatectomy	569 patients	Nurse-to-patient ratio	Mortality *OR*=0.49 (0.18, 1.29) LOS *increase in days*=0.67 (-0.80, 0.93) Pneumonia *crude OR*=1.4 (0.6, 3.5)	Age, sex, nature of admission, type of operation, comorbid

Study	Place	Design	Specialty/ patient group	Sample	Nurse staffing measures	Results	Adjustment
						Pulmonary failure *crude OR*=3.6 (1.3, 10.1)	conditions, hospital and surgeon volumes
Elting (2005)[77]	US	Cross-sectional	Bladder cancer patients underwent cystectomy	1,302 patients	RN-occupied bed ratio	Mortality *OR*=0.43 (0.19, 0.97)	Age, hospital volume, comorbid conditions
Farley (1992)[78]	US	Cross-sectional	Patients with acute myocardial infarction	974,803 patients	RN FTE/100 patient days	Mortality regression *coefficient*=-3.08	Patient and hospital characteristics, primary care physicians on staff, medical specialists board certified.
Fridkin (1996)[79]	US	Retro-spective case-control and cohort	ICU (surgical)	1,760 patients	RN-patient ratio	Central venous catheter-associated bloodstream infections (reference: no. of patient/nurse = 1) 1.2 patients/nurse *OR*=3.95 (1.07, 14.54) 1.5 patients/nurse *OR*=15.6 (1.15, 211.4) 2 patients/nurse *OR*=61.5 (1.23, 3074)	Number of patients on >14 days assisted ventilation, total parental nutrition, period of hospitalization
Haley (1982)[80]	US	Cross-sectional	Neonatal units	1,7076 patients	Nurse-to-patient ratio	Staphylococcal infection rate *Rate ratio*=6.23 (1.38, 28.1)	Hexachlorophene bathing, summer, overcrowding
Harless (2010)[81]	US	Cross-sectional	General	11,945,276 patients	RN FTE/1,000 patient days	Mortality ratio *marginal effect* (from 50th percentile) =-0.040, *s.e.*=0.018 FTR ratio *marginal effect* (from 50th percentile) =-0.070, *s.e.* = 0.035	Hospital characteristics, previous year's quality of care, staffing levels for LVN and aide
Kovner (1998)[82]	US	Cross-sectional	Surgical patients	598 hospitals	RN FTE/adjusted patient day	Urinary tract infection *coefficient*=-637 (-853, -421) Pneumonia *coefficient*=-159 (-253, -66) Pulmonary compromise after major surgery *coefficient*=-60 (-118, -2)	Ownership, bed size, hospital resources, region, teaching status, hospital's relationship with managed-care organization
Liang	Taiwan	Cross-	General	32	Nurse-to-pati	Mortality *OR*=3.62 (1.93-6.78)	Age, ward, medical center,

Study	Place	Design	Specialty/ patient group	Sample	Nurse staffing measures	Results	Adjustment
(2012)[83]		sectional		hospitals	ent ratio		regional hospital, healthcare workforce-bed ratio, technology equipment-bed ratio
Liu (2012)[84]	Taiwan	Cross-sectional	General	1,358 nurses	Nurse-to-patient ratio	NPR ≤ 7 (reference) vs 8-9, 10-11, >11 Falls *ORs* range 1.51-5.14 Pressure ulcers *ORs* range 1.72-2.74 Medication error *ORs* range 1.19-4.13 Rescue failure *ORs* range 0.36-1.46 Unplanned extubation *ORs* range 2.4-5.58 Hospital-acquired pneumonia *ORs* range 0.86-1.60 Hospital-acquired urinary tract infection *ORs* range 1.05-1.62	Education, clinic ladder, institutions
Marcin (2005)[85]	US	Cross-sectional	ICU (pediatrics)	220 patients	Nurse-to-patient ratio	Unplanned extubation *OR*=4.24 (1.00-19.1)	Age, illness severity, continuous sedation infusion, use of restraints, patient agitation, nurse experience
Mark (2004);[86] Mark (2005)[87]	US	Cross-sectional	General	422 hospitals	RN FTE/1,000 patient days	Mortality ratio *coefficient*=-0.30, *s.e.*=0.005 Pneumonia complication ratio *coefficient*=-0.041, *s.e.*=0.011 Urinary tract infection ratio *coefficient*=-0.066, *s.e.*=0.012 Decubitus complication ratio *coefficient*=-0.045, *s.e.*=0.01 LOS ratio *coefficient*=-0.026, *s.e.*=0.003	Disease stage, age, gender, admission type, admission source, type of treatment (complication – severity-adjusted models)
Mefford (2011)[88]	US	Cross-sectional	ICU (neonatal)	235 patients	RN-patient ratio	Nosocomial infection in neonatal ICU *r*=-0.112, n.s.	Nil

Study	Place	Design	Specialty/ patient group	Sample	Nurse staffing measures	Results	Adjustment
						Nosocomial infection in Immediate care nursery *r*=-0.074, n.s.	
Newhouse (2005)[89]	US	Cross-sectional	Surgical patients	1,894 patients	RN-patient ratio	Mortality *OR*=1.0 (0.48-1.09) LOS≤7 days *OR*=0.89 (0.64, 1.24)	Age, gender, race, comorbidities, rupture, admitting code, extubation, hospital volume
Profit (2010)[90]	US	Prospective cohort	ICU (neonatal)	850 patients	RN-patient ratio	Nosocomial infection *coefficient*=-0.44, *s.e.*=0.83	Birth weight, gender, race, illness severity, ICU size, site of care
Rafferty (2007)[91]	UK	Cross-sectional	Surgical patients	118,752 patients	Nurse-to-patient ratio	Mortality (reference: highest NPR) *ORs* range 1.14-1.26 FTR *ORs* range 1.16-1.29	Hospital, patient, and nurse characteristics
Robert (2000)[92]	US	Nested case-control	ICU (surgical)	127 patients	Nurse/patient day	n.s. association with primary bloodstream infection. No estimate provided	
Sasichay-Akkadechanunt (2003)[93]	Thailand	Cross-sectional	Medical / surgical	2,531 patients	Nurse-to-patient ratio	Mortality OR=0.27 (0.17, 0.43)	Principal diagnosis, source of admission, complication, operation, illness severity, nurse characteristics
Schilling (2010)[94]	US	Cross-sectional	Medical / surgical patients	166,920 patients	RN FTE/patient day	Mortality *OR*=0.94 (0.89, 0.99)	Hospital occupancy, weekend admission, influenza outbreak
Stegenga (2002)[95]	Canada	Cross-sectional	Pediatrics	2,929 patients	Nurse-to-patient ratio	Nosocomial viral gastrointestinal infection rate *r*=0.56, sig.	Nil
Tarnow-Mordi (2000)[96]	UK	Prospective cohort	ICU	1,025 patients	Nurse-to-patient ratio	Mortality (reference: ≤1.5 nurse/bed per shift) 1.51-1.60 nurses/bed *OR*=1.1 (0.7, 1.7) 1.61-1.70 nurses/bed *OR*=1.6 (1.1, 2.6) >1.70 nurses/bed *OR*=1.9 (1.2, 2.9)	Predicted risk of mortality
Hamilton	UK	Prospective	ICU	13,515	RN-patient	n.s. association between RN-patient ratio	Gestation, predicted

Study	Place	Design	Specialty/ patient group	Sample	Nurse staffing measures	Results	Adjustment
(2007);[97] Tucker (2002)[98]		cohort	(neonatal)	patients	ratio; specialist nurse-to-patient ratio	and mortality ratio Association between specialist nurse-to-patient ratio (<1.0 as reference) and mortality ratio 1.0-1.2 NPR *OR*=0.63 (0.37, 1.10) 1.3-1.8 NPR *OR*=0.52 (0.33, 0.83) >1.8 NPR *OR*=0.57 (0.31, 1.08)	mortality
Vicca (1999)[99]	UK	Cross-sectional	ICU	Unclear	Nurse-to-patient ratio	MRSA rate *r*=-0.15 (-0.065, -0.225)	Nil
Zhu (2012)[100]	China	Cross-sectional	Medical / surgical	5,430 patients	Nurse-to-patient ratio	≥0.6 nurse per patient (reference) vs 0.4 vs 0.4-<0.5 vs 0.5- <0.6 Surgical site infections *ORs* range 1.23-1.55 Wrong medication dose *ORs* range 1.17-1.68 Pressure ulcer *OR*s range 1.19-1.89	Demographics, hospital characteristics, unit type, aggregated nurse skill mix
Al-Kandari (2008)[38]	Kuwait	Cross-sectional	Medical / surgical	780 nurses	RN-patient ratio	Patient falls *r*=0.104 Pressure ulcer *r*=0.075	Nil
Dorsey (2000)[101]	US	Cross-sectional	ICU (surgical)	52 patients	RN-patient ratio	"Temporal relation between the high infection rates during the outbreak months and periods when staffing of registered nurses were at their lowest"	Monthly patient-days
Halm (2005)[102]	US	Cross-sectional	Surgical patients	2,709 patients	Nurse-to-patient ratio	n.s. association with mortality and failure to rescue. No estimate provided.	Nil
Person (2004)[103]	US	Cross-sectional	Medical patients	118,940 patients	FTE RN/average daily census	Mortality (reference: quartile 1, lowest staffing level) Quartile 4 *OR*=0.91 (0.86, 0.97) Quartile 3 *OR*=0.94 (0.88, 1.00) Quartile 2 *OR*=0.96 (0.90, 1.02)	Skill mix, patient characteristics, teaching status, urban, technology, receipt of therapy
Unruh (2012)[104]	US	Cross-sectional	General	124 hospitals	FTE RN/patient	Decubitus ulcer *estimate*=0.22, n.s. FTR *estimate*=-0.009, n.s.	Latent growth curve model

Study	Place	Design	Specialty/ patient group	Sample	Nurse staffing measures	Results	Adjustment
					day	Infections *estimate*=-2.874, sig.	
Shortell (1994)[105]	US	Prospective	ICU (medical / surgical)	17,440 patients	RN/adjusted patient day	Risk-adjusted mortality beta=0.12, *s.e.*=0.137 Risk-adjusted LOS beta=0.03, *s.e.*=0.087	Technological availability, diagnostic diversity
Silber (1995)[106]	US	Cross-sectional	Surgical patients	73,174 patients	RN-to-bed ratio	Mortality *spearman r* = -0.38 Failure *spearman r* =-0.45	Nil
Houser (2005)[107]	US	Cross-sectional	General	5,636,496 patients	RN FTE/average daily census	Decubitus ulcer *rate ratio*=0.77 (0.71, 0.83) FTR *rate ratio*=0.92 (0.88, 0.96) Post-operative respiratory failure *rate ratio*=0.94 (0.77, 1.15)	Hospital characteristics

Interpretation of effect sizes depended on the definitions of nurse staffing measures and the unit change/reference group of the effect size estimates.
FTE, full-time equivalent. FTR, failure to rescue. ICU, intensive care unit. LOS, length of stay. NPR, nurse-to-patient ratio. OR, odds ratio. RN, registered nurse. UK, the United Kingdom. US, the United States. VAP, ventilator-assisted associated pneumonia.

3.6.2. Mortality

An increase of one nurse FTE per patient day was associated with 14% lower odds of mortality (OR = 0.86; 95% CI 0.78, 0.96). Among the studies which used standardized mortality ratio as the outcome, one additional patient per nurse per shift was associated with higher risk of mortality (Figure 1). However, this relationship was less clear in ICUs. One additional nurse FTE per patient day was not associated with increased mortality in ICUs (OR=0.93; 95% CI 0.66, 1.30; Table 13; pp. 40). Shortell[104] did not observe an increased standardized mortality ratio with one more patient per nurse per shift (Figure 2). The studies in ICUs that used nurse-to-patient ratios in categorical groups found that the risk of mortality was comparable between ICUs with higher (>1:1.5) and lower level of nurse staffing (1:1.5-1:1.9 and ≤1:2.0) (Table 13; pp. 40). Results of studies in medical-surgical units that used nurse-to-patient ratios in categorical groups were not synthesized because of the large variations in the nurse staffing group ranges.[83,89,96,103,108]

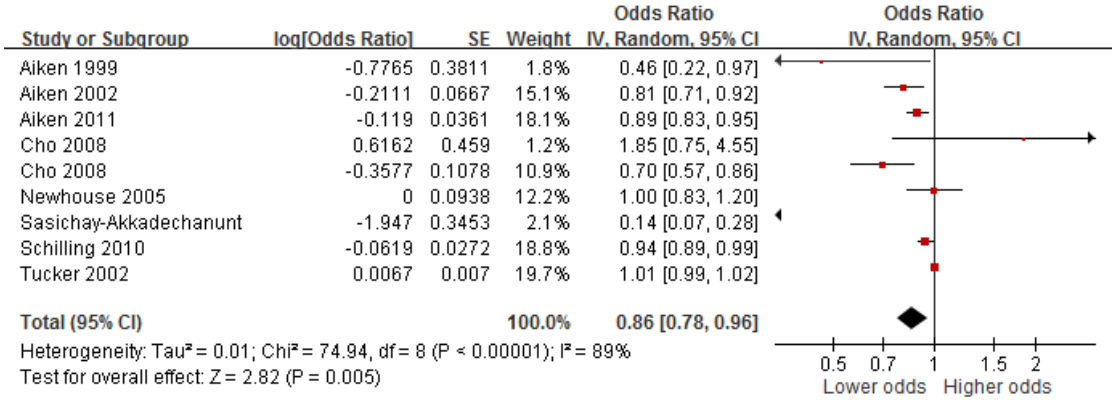

Figure 1. Increasing one nurse FTE per patient day and mortality
The two estimates provided by Cho (2008) corresponded to the estimates in secondary hospitals (general hospitals providing limited specialized services) and tertiary hospitals (referral-only hospitals providing highly specialized services).

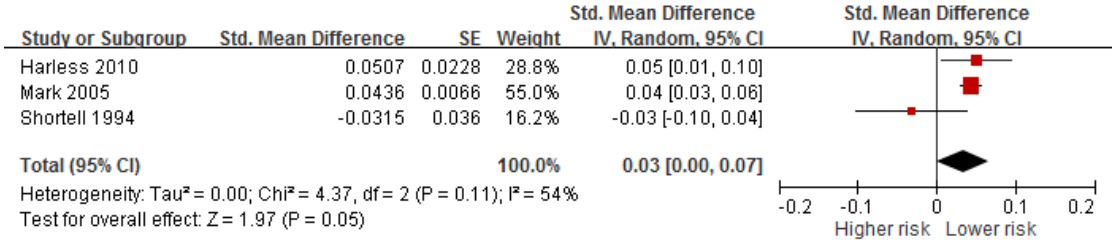

Figure 2. Increasing one patient per nurse per shift and standardized mortality ratio

Table 13. Nurse-to-patient ratios and mortality in ICUs

Mortality in ICU	No. of estimates	Pooled OR (95% CI)
Group 1 (nurse-to-patient ratio >1:1.5) *vs* Group 2 (nurse-to-patient ratio 1:1.5 to 1:1.9)†	2	2.43 (0.54, 10.97)
Group 1 (nurse-to-patient ratio >1:1.5) *vs* Group 3 (nurse-to-patient ratio ≤1:2.0)†	1	2.04 (0.76, 5.46)
Group 2 (nurse-to-patient ratio 1:1.5 to 1:1.9) *vs* Group 3 (nurse-to-patient ratio ≤1:2.0)†	1	0.70 (0.3, 2.0)

†Reference group.
ICU, Inensive care unit. OR, odds ratio.

3.6.3. Failure to rescue

As shown in Figure 3, an additional nurse FTE per patient day was associated with lower odds of failure to rescue (OR=0.86; 95% CI 0.79, 0.94). Nurse-to-patient ratios below 1:11 in medical-surgical units were significantly associated with higher odds of failure to rescue than nurse-to-patient ratios greater than 1:8 (Table 14; pp. 41). No difference in failure to rescue was found between nurse-to-patient ratios at >1:1.8 and 1:1.8-1:10.9.

Results of five studies were not synthesized due to either a different outcome/effect size measure used[47,81,107] or inadequate details of the effect size reported.[102,104] Harless[81] found that additional nurses contributed to significantly lower the rate of failure to rescue and the effect sizes strengthened when the nurse-to-patient ratios were higher. In other words, the effect of an additional nurse was greatest in hospitals with the highest level of nurse staffing. Another two studies[47,107] reported a significantly lower failure to rescue rate with increased nurse staffing whereas the remaining two studies[102,104] reported a null relationship.

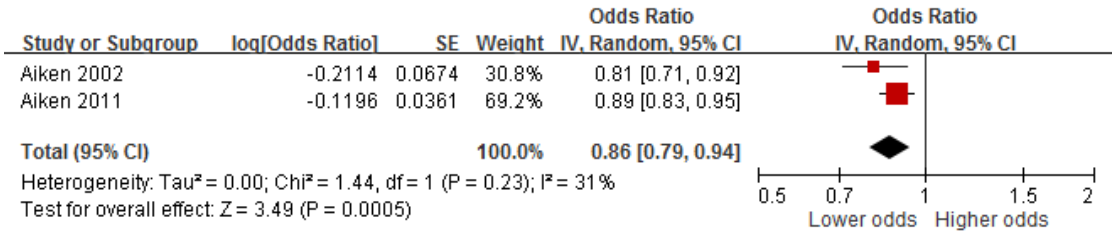

Figure 3. Increasing one nurse FTE per patient day and failure to rescue

Table 14. Nurse-to-patient ratios and failure-to-rescue in medical-surgical units

Mortality in ICU	No. of estimates	Pooled OR (95% CI)
Group 1 (nurse-to-patient ratio >1:8) *vs* Group 2 (nurse-to-patient ratio 1:8-1:10.9)†	3	1.06 (0.55, 2.05)
Group 1 (nurse-to-patient ratio >1:8) *vs* Group 3 (nurse-to-patient ratio <1:11)†	3	0.81 (0.67, 0.89)

†Reference group.
ICU, Inensive care unit. OR, odds ratio.

3.6.4. Medication errors

Two Chinese studies[84,100] explored the relationship between nurse-to-patient ratios and medication errors. Liu did not find any relationship between nurse-to-patient ratios and medication errors. Zhu[100] reported that the nurse staffing level at 0.4 to <0.5 nurse per patient was associated with higher odds of giving wrong medication dose than nurse staffing level at ≥0.6 nurse per patient. However, <0.4 nurse per patient was not associated with higher odds of medication errors. A linear relationship between staffing and outcome was not established in this study. There was thus no consistent evidence showing a relationship between nurse-to-patient ratio and occurrence of medication errors.

3.6.5. Length of stay

As seen in Figure 4, the pooled analysis showed that nurse-to-patient ratio at 1:2 or higher in ICUs significantly reduced the length of stay by 27.6% (95% CI -45.9, -9.4). However, the result may overestimate the true effect because some of the studies were not included in the pooled analysis. Dimick[76] did not report the effect size of the insignificant relationship. Another ICU study[105] which examined risk-adjusted length of stay (ratio of actual to expected length of stay) did not find a significant relationship with nurse-to-patient ratio. The relationship between nurse-to-patient ratio and length of stay in medical-surgical units was unclear. Mark[87] reported that one more FTE nurse per 1,000 patient days was associated with 1.4%-2.9% decrease in the length of stay. Results of another two studies were insignificant. Kutney-Lee[63] reported that the change in the number of patients per nurse from 4 to 5 was associated with 1% increase in the length of stay but the finding was insignificant. Another study[89] also reported that number of perioperative nurses (1 vs 2) assigned per each surgical patient was not related to extended length of stay (i.e. >7 days).

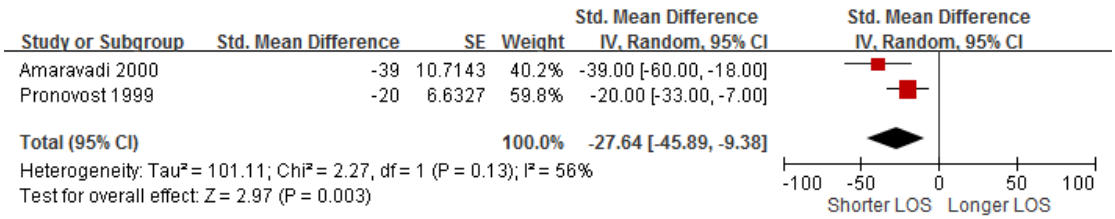

Figure 4. Comparison of change in length of stay between higher nurse staffing (1:1-1:2) and lower nurse staffing (<1:2) in ICUs

3.6.6. Pressure ulcer

It appeared that there was a consistent inverse relationship between nurse-to-patient ratio and the incidence of pressure ulcer (also known as decubitus ulcer). No pooled analysis was conducted because of the substantial variations in the nurse staffing, outcome, and effect size measures. The study by Liu[84] reported that the more the number of patients taking care by a nurse, the higher the odds of developing pressure ulcers. Other studies which examined the relationship reported consistent findings.[38,47,100,107] Cook[47] further explored the change in patient-to-nurse ratio before and after the implementation of mandated staffing ratio in California hospitals. The results showed that the increase in nurse staffing led to a significant decrease in pressure ulcer rate. However, Unruh[104] who explored the staffing-outcome relationship using the latent growth curve models reported an insignificant relationship with pressure ulcers.

3.6.7. Pneumonia

As seen in Figure 5, the pooled analysis suggested that higher staffing in ICUs was associated with lower odds of pneumonia (OR=0.51; 95% CI 0.30, 0.87). Participants of the two studies that were included in the analysis were adult ICU patients who had underwent either esophagectomy or hepatectomy.[68,76] Some preliminary data from studies conducted in general medical-surgical units suggested consistent findings. Mark[86] found that an additional registered nurse FTE per 1,000 patient days was associated with lower pneumonia risk, except in hospitals with the highest levels of nurse-to-patient ratio. Liu[84] did not find a significant relationship between nurse-to-patient ratio and risk of pneumonia, except that the work shifts with more than 11 patients per nurse was significantly associated with higher odds of hospital-acquired pneumonia than the work shifts with 7 patients or below.

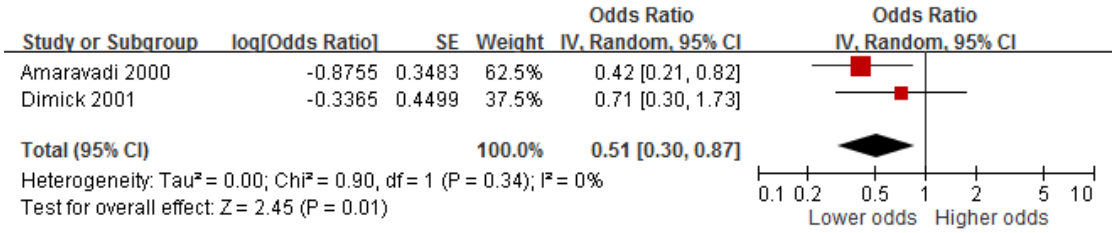

Figure 5. Comparison of pneumonia between higher nurse staffing (1:1-1:2) and lower nurse staffing (<1:2) in ICUs

3.6.8. Pulmonary insufficiency/ failure

Dimick[76] and Pronovost[75] explored the association between nurse staffing and risk of pneumonia in ICU surgical patients (Figure 6). The former study included adult ICU patients who underwent hepatectomy whereas the latter study included ICU patients who underwent abdominal aortic surgery. The pooled analysis showed that lower odds of pulmonary insufficiency or failure was associated with higher nurse-to-patient ratio (OR=0.31; 95% CI 0.24, 0.40). However, the study by Houser,[107] which examined all hospital discharge cases, reported null findings (results not included in the pooled analysis).

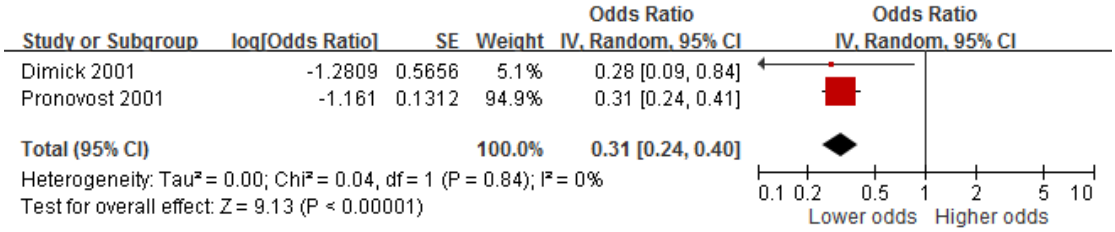

Figure 6. Comparison of pulmonary insufficiency between higher nurse staffing (1:1-1:2) and lower nurse staffing (<1:2) in ICUs

3.6.9. Nosocomial infections

The outcome of nosocomial infections referred to general hospital-acquired infections or specific types of infections such as bloodstream infection, staphylococcal infection, post-operative infection, and viral gastrointestinal infection. Among the ten studies

examining the relationship between nurse-to-patient ratio and nosocomial infections, five studies reported a significant association and the remaining five studies reported null findings. Four out of the five studies with insignificant findings examined the relationship in surgical or pediatric ICU patients.[67,68,88,90,92]

Among the five studies[79,80,95,100,104] which reported significant association, two were from pediatric units, two from medical-surgical units, and one from ICU. However, interpretation of results should be cautiously made because of the study limitations. Stegenga[95] explored the relationship using Pearson correlation without adjustment for potential confounders. Although Fridkin[79] reported a dose-response relationship between nurse staffing and infection, the wide confidence intervals made the interpretation difficult. The study by Zhu[100] only found a significant association between the highest staffing group (≥0.6 nurse per patient) and the lowest staffing group (<0.4 nurse per patient), whereas the medium staffing levels (0.4 - <0.6) had comparable risk of infection to the lowest staffing group (≥0.6 nurse per patient).

3.6.10. Urinary tract infection

Preliminary evidence showed that urinary tract infection was related to nurse staffing. Mark[86] reported that one unit increase in nurse FTE per 1,000 patient days decreased the risk of urinary tract infection. Liu[84] reported that compared with nurse-to-patient ratio at ≤7, more than 11 patients per nurse increased the odds of urinary tract infection by 62%.

3.6.11. Unplanned extubation

Liu[84] reported a dose-response relationship between nurse staffing level in general medical-surgical patients and the odds of unplanned extubation. Compared with staffing level at one nurse to ≤7 patients, staffing level lower than 1:7 was associated with 2-fold to 5-fold increase in the odds of unplanned extubation. Similarly, another study[85] reported that pediatric ICU patients experienced higher odds of unplanned extubation if one nurse had to take care of 2 children instead of one child.

3.6.12. Patient falls

Al-Kandari[38] reported a positive correlation between the number of patients assigned to a nurse and the incidence of patient falls with injury (r = 0.104). Liu[84] reported that work shifts with more than 11 patients assigned to a nurse increased the risk of

patient falls compared with work shifts with ≤7 patients assigned to a nurse.

3.6.13. Methicillin-resistant staphylococcus aureus acquisition

Vicca[99] found a negative correlation between the number of Methicillin-resistant staphylococcus aureus acquisition and the number of nurses per patient per shift. The results remained unchanged regardless of the nurse-to-patient ratio was measured using the highest, the lowest, or the mean ratio during the three shifts of the day.

3.7. Subgroup analysis

One major criticism of using nurse-to-patient ratio is that the measure itself does not take nurse experience and educational qualification into account. It is reasonable to believe that a high component of enrolled nurses in the staff mix may not lead to positive outcome if patient acuity is high. Further analysis was conducted to pool studies using registered nurse-to-patient ratios. If the study did not describe whether the nurse-to-patient ratio included registered nurses or all types of nursing staff, the latter was assumed.

As seen in Table 15 (pp. 46), the pooled analysis showed that an additional registered nurse FTE per patient day was associated with decreased mortality (OR=0.87; 95% CI 0.80, 0.96). The results still held when the analysis was restricted to only medical-surgical units (OR=0.90; 95% CI 0.83, 0.97). Consistent with the primary analysis, registered nurse-to-patient ratio was not associated with mortality in ICUs (OR=1.03; 95% CI 0.40, 2.61).

The respective pooled odds ratio for failure to rescue would be the same as that in the primary analysis (Figure 3) because all selected studies used registered nurse-to-patient ratio. Preliminary data suggested that one unit increase in registered nurse FTE per patient day reduced the odds of failure to rescue by 14% (95% CI 0.79,0.94). Subgroup analysis for other patient outcome was not carried out because of the limited number of studies.

Table 15. Pooled odds ratio of mortality with one unit increase in registered nurse FTE per patient day by specialty units

	No. of studies	Pooled odds ratio (95% CI)	I^2
All nurses in all units	9	0.86 (0.78, 0.96)	89%
All nurses in medical-surgical units	6	0.82 (0.70, 0.95)	87%
All nurses in intensive care units	3	0.93 (0.66, 1.30)	85%
Registered nurses only in all units	7	0.87 (0.80, 0.96)	66%
Registered nurses only in medical-surgical units	5	0.90 (0.83, 0.97)	56%
Registered nurses in intensive care units	2	1.03 (0.40, 2.61)	77%

3.8. Summary of the meta-analysis

This review summarized studies with the aim to explore the impacts of nurse staffing ratios on quality of nursing care as represented by a range of nurse-sensitive patient outcomes. The pooled analysis suggested that many of the patient outcomes were related to nurse-to-patient ratios. Having fewer patients per nurse was consistently associated with reduced mortality, failure to rescue, pressure ulcers, and pneumonia. Preliminary findings also suggested an inverse relationship of staffing ratios with length of stay in ICUs, pulmonary failure, patient falls, and Methicillin-resistant staphylococcus aureus acquisition. The relationships of staffing ratios with nosocomial infections, unplanned extubation, and medication errors were inconclusive.

3.9. General Discussion

3.9.1. Staffing ratios and patient outcomes

The most consistent finding was that higher staffing ratio was related to reduced mortality. This relationship was apparent at least in medical-surgical settings. More importantly, the relationship still held regardless of whether nurse-to-patient ratio or registered nurse-to-patient ratio was used. The odds ratio of hospital mortality associated with one registered nurse FTE increase per patient day (OR=0.87; 95% CI 0.80, 0.96) was highly comparable to the one reported in the primary analysis (OR=0.86; 95% CI 0.78, 0.96). Considering that results from most of the selected studies had been adjusted for hospital and patient characteristics, nurse-to-patient ratio is probably an independent predictor of patient outcome. Since both nurse-to-patient

ratio and registered nurse-to-patient ratio predicted hospital mortality, we argued that number of nurses *per se* is a sensitive administrative tool for monitoring service quality. Due to paucity of studies, this review had not examined the number of enrolled nurses or licensed practical (vocational) nurses in relation to patient outcomes. Elting[64] found that a higher registered nurse-occupied bed ratio predicted inpatient mortality whereas licensed practice nurse-occupied bed ratio had no association. Likewise, Mark[86] could not establish an association between licensed practice nurse-to-patient ratio and pneumonia, urinary tract infection, and decubitus ulcer complications. However, the number of licensed practice nurses/enrolled nurses may indirectly affect patient outcomes. If hospital administrators replace registered nurses with more licensed practice nurses/enrolled nurses (fewer registered nurses resulted) in face of manpower shortage and budget constraints, they may compromise the quality of patient care. The impact of the recent re-opening of training courses for enrolled nurses in Hong Kong should be carefully considered and monitored.

Further explorations found that the effects of staffing ratios on mortality mainly were contributed by studies from general medical-surgical units. Mortality in ICUs was not reduced with additional nurse staffing. Results were consistent with a review conducted by Numata et al.[109] The authors selected a group of studies examining the relationship between nurse-to-patient ratio and hospital mortality. Although a higher staffing level in ICUs was associated with a lower unadjusted risk of mortality (risk ratio=0.65; 95% CI 0.47, 0.91), the association did not persist after adjusting for confounders. The adjusted risk ratio was not reported but the review indicated that 4 of the 5 selected studies[68, 75-76, 96, 103] failed to demonstrate a significant association with mortality after adjusting for covariates. Numata[109] attributed the insignificant findings to several methodological challenges, especially with regard to the measurement of nurse staffing and confounding factors. Critical care setting is characterized by the high patient acuity and intensive nursing input. An explanation was that more nurses were assigned to more severely ill patients at high risk of mortality. This perspective was supported by Tarnow-Mordi[96] who observed an increased risk of mortality with higher nursing requirement per occupied bed per shift (odds ratios 1.1-1.9). In other words, illness severity was a major confounding factor in the staffing-outcome relationship. An alternative explanation of the insignificant finding was that number of nurses with specialist qualification or experience in ICU nursing would determine patient outcome. The UK Neonatal Staffing Study[97] found that a higher specialist nurse provision ratio reduced infant mortality in neonatal ICU but a higher registered nurse provision ratio did not. A study of a surgical ICU[92] compared two admission periods with different levels of

regular nurse staffing. Patients admitted during the period with more regular nurses and fewer pool nurses had lower rate of primary bloodstream infection. It is reasonable to expect that nurses with specialized experience in critical care setting are more capable of making appropriate and timely clinical decisions and hence make a difference in patient outcome. To confirm this hypothesis, future ICU studies should consider specialized and non-specialized nursing staffing separately.

Despite of the insignificant relationship between nurse staffing and hospital mortality in critical care settings, it is misleading to conclude that nurse-to-patient ratio does not play a role in quality care. Instead, fewer nurses in ICU may lead to longer length of stay[68, 74] and higher risk of postoperative complications,[75] central venous catheter-associated bloodstream infections,[79] unplanned extubation,[85] and Methicillin-resistant staphylococcus aureus infection.[99] A few more unselected studies demonstrated that more ICU nurses reduced the risk of nosocomial infection and late-onset ventilator-associated pneumonia.[110-112] These studies were not selected because their definition of nurse-to-patient ratio did not strictly meet the inclusion criteria. Further explorations should use a standardized staffing measure and adjust for important confounders such as illness severity.

3.9.2. Translating findings into local practice

This systematic review has employed meta-analytic techniques to summarize findings from observational studies. Unlike other published systematic reviews,[51-56] this review aimed to study one nurse staffing variable of interest (ie, nurse-to-patient ratio). In view of the strong empirical evidence showing a probable relationship between nurse-to-patient ratio and patient outcome, this review takes the first local initiative to recommend staffing standards in various clinical settings (Table 16; pp. 49). The proposed ratios are in line with international guidelines (Table 9; pp. 22). In brief, staffing ratio in general medical-surgical units during day time is recommended to be 1:4-1:6. A higher nurse-to-patient ratio should be assigned to units with critically ill patients (1:2) and pediatric patients (1:4). The recommended ratios are not intended to serve as a gold standard but a reference for manpower planning and service evaluation. The ratios may be modified when new empirical evidence emerges.

Table 16. Recommended nurse-to-patient ratios in public hospitals in Hong Kong

	Existing staffing ratios (AHKNS Survey[8])			Our recommended staffing ratios		
	AM	PM	Night	AM	PM	Night
Medical (including geriatrics)	1:11	1:12	1:24	1:4-1:6	1:4-1:6	1:8-1:10
Surgical	1:10	1:10	1:18	1:4-1:6	1:4-1:6	1:8-1:10
Adult intensive care	-	-	-	1:2	1:2	1:2
Pediatrics	1:6	1:6	1:11	1:4	1:4	1:6
Obstetrics	1:13	1:14	1:28	1:4-1:6*	1:4-1:6*	1:8-1:10*
Orthopedics & traumatology	1:10	1:10	1:20	1:4-1:6	1:4-1:6	1:8-1:10
Psychiatry	1:11	1:11	1:30	1:4-1:6† 1:4‡	1:4-1:6† 1:4‡	1:8-1:10† 1:6‡

* Ante-partum and post-partum care.
† Adult psychiatry.
‡ Child psychiatry.

As mentioned in Section 1.1 (pp. 5), understaffing of nurses in public hospitals in Hong Kong is a territory-wide observation. A local survey conducted by the AHKNS reported that the average nurse-to-patient ratios in public hospitals were 1:11 in morning shifts, 1:12 in evening shifts, and 1:24 in night shifts.[8] Almost all nurses in any hospital cluster have to provide care to at least 10 patients in morning and evening shifts or at least 18 patients in night shifts. The staffing level was far below the international standards (Table 9; pp. 22) and those in developed countries. Hospitals in California had an average staffing ratio of 1:5.08 before regulation and 1:4.08 after regulation.[47] Thompson[113] criticized that Hong Kong lacked strategic plans to forecast and determine the nursing workforce demand. While the Administration of the Hospital Authority estimates that 600 additional nurses are required per year,[6] this number of nurse requirement has not been based on explained criteria.

3.9.3. Staffing in psychiatry

None of the selected studies in the review investigated safe staffing in psychiatry. The past intense interest in determining nurse staffing did not adequately extend to psychiatric care. Past studies either included psychiatry as one of the general medical units or excluded data from psychiatric units. Ford[114] surveyed 118 acute psychiatric units in the United Kingdom and found that there was an average of 0.3 nurse on duty per patient at the time of visit. The actual number of staffing per patient was below the estimated need across locations, especially in inner and outer London. To determine the safe staffing level, it would be necessary to establish a link between staffing and outcome. However, the general outcome indicators that were used in general medical-surgical units might not be specific in psychiatric nursing. Not until 2008, the Joint Commission issued 7 core measures for hospital-based inpatient psychiatric services.[115] Among those, hours of physical restrain use and hours of seclusion appear to be psychiatric-specific measures for patient outcomes.

Table 17 (pp. 51) is a summary of past studies which examined staffing levels and various outcomes. Although staffing ratio was the most common measure, a few studies counted all types of clinical staff members in the analysis. Some of the other studies used nursing hours per patient day and regular staff absence as the staffing measures. These studies had diverse outcomes of interest that each study used a different outcome measure. Preliminary evidence shows that a higher staffing level in acute psychiatric units may be associated with lower emotional exhaustion, decreased length of stay, fewer adverse incidents, and more staff-patient interactions. The RCP has not updated the minimum staffing standards in inpatient psychiatric units since late 1990s (Table 8; pp. 21). Due to the paucity of research studies, the APNA did not suggest minimum staffing ratios, but recommended individual hospitals to develop their own staffing plans to allow shift-to-shift flexible adjustments (e.g. based on acuity factor).[40] APNA further proposed that the quality of care could be measured by medication errors, patient and staff injury, seclusion and restraint rates, and some other nurse outcome variables.

Table 17. Nurse staffing in psychiatric units

Study	Staffing measures	Outcome	Results
Hanrahan et al.[116]	Patient to nurse staffing ratio	Nurse burnout	Higher psychiatric nurse-to-patient ratio was associated with lower emotional exhaustion
Shamian et al.[117]	Hours per patient day	Length of stay	An increase of 0.25 hour per patient day was associated with 1 day decrease in length of stay
Sandford et al.[118]	Patient to staff ratio	Staff-patient interaction and staff-staff interaction	More patients a nurse cared for was associated with a decrease in staff-staff and staff-patient interaction
Bowers et al. (2007)[119]	Regular staff absence (leave or vacancy)	Adverse incidents (physical and verbal aggression, property damage, self-harm, and abscondence)	Higher regular staff absence was associated with higher likelihood of adverse incidents
Coleman &Paul[120]	Clinical staff-patient ratio	Unit effectiveness (community tenure)	Staffing ratio did not predict unit effectiveness when other covariates were considered
Lanza et al.[121]	Patient-staff ratio	Physical assaults by patients	No relationship between patient-staff ratio and assaults
Ellsworth et al.[122]	Number of patient/nurse	Treatment effectiveness (adjustment and role skills)	No relationship
Kellam et al.[123]	Number of patients/staff member	Symptom improvement	Wards with a high level of disturbed behavior and a low level of social contact tended to have fewer patients per staff member

3.9.4. Challenges and opportunities

This review has provided the best available empirical evidence that supports an independent relationship between nurse-to-patient ratio and patient outcomes. As discussed in Section 2.3 (pp. 23), it is highly challenging to develop a randomized control trial that tests the optimal staffing ratios. A recent Cochrane review[124] investigated the effect of hospital nurse staffing models on patient outcomes. Only 15 interventional studies were identified. The selected randomized controlled studies explored an addition of specialist nurse or support staff in relation to patient and staff-related outcomes. The pool analysis showed that an addition of specialist nurse reduced length of stay and risk of pressure ulcers. However, none of the study explored patient outcomes with different nurse-to-patient ratios.

The meta-analysis in this systematic review assumed the effect of an additional nurse FTE per patient day was the same at different staffing levels (ie, a linear relationship). Mark[86] argued that additional staff would produce a diminished marginal effect on patient outcomes. In other words, an additional nurse FTE per patient day will generate greater positive effect in hospitals with very low staffing ratios than those with higher staffing ratios. Assuming the diminished marginal effect is true, the ground and motivation to improve nurse staffing ratio in Hong Kong is further strengthened because the baseline (current) staffing ratio is so low.

A better nurse-to-patient ratio does not only improve patient outcome, it also improves job satisfaction and staff retention. A survey[125] with an aim to assess the nurse satisfaction after the implementation of minimum staffing regulation reported that nurse respondents obtained significant greater job satisfaction, especially with regard to the adequacy of registered nurse staffing, amount of paper work and clerical support, benefits, and relationships with other staff and patients. Buchan[126] agreed that the minimum staffing regulation was an attractive tool to attract new members to the nursing workforce. According to the California Nurses Association,[22] the enactment of the regulation resulted in an increase of 100,000 new active licensed registered nurses in California between 1999 and 2009. The minimum staffing regulation in California did not only increase the ratio of nurses to patients but also other staffing indicators including nursing hours by both registered nurses and licensed vocational nurses. Hospitals with lower initial staffing level experienced a greater improvement in staffing ratios and nursing hours between the pre- and post-regulation period.[127]

4. Standards for supervisory nurse staffing

Nursing management is a relatively unexplored area in terms of its relationship with quality of care. Nurse managers or charge nurses often provide minimal direct care to patients, but they are considered no less important than frontline nurses in the delivery of quality of care.[128] In Victoria and New South Wales, Australia where mandated staffing ratios were implemented, staffing of charge nurse was specifically addressed. Victoria hospitals required one charge nurse to be assigned to a unit across most of the specialties during am and pm shifts, irrespective of the number of patients or occupied beds (Table 4; pp. 15). New South Wales recommended a charge nurse to be assigned to a unit during pm shifts (Table 5; pp. 16). Other available recommendations are illustrated in Table 18 (pp. 55). For instance, BACCN recommended that a senior nurse should be assigned to an adult critical care unit with more than 6 beds. RCOG, RCMW, RCA, & RCPCH suggested that there should be one WTE consultant midwife to oversee 900 low-risk women under midwifery care per year. These clinical guidelines acknowledged that additional supervisory nurses are key personnel to oversee daily clinical operations and to maintain quality of care. However, the optimal staffing, educational qualification, and level of management skills of nurse managers have not been adequately addressed. For example, the PICS addressed the staffing level for pediatric intensive care but did not specify the roles of the nurse in-charge. The BAPM, however, addressed the roles of neonatal nurse consultant but the intensity of staffing was not mentioned.

Previous analysis (Section 3; pp. 26) of the relationship between nurse staffing and patient outcome did not include nurse managers as part of the staffing. Our knowledge about the role of nursing management in quality of care has been limited by the scanty empirical evidence. One of the key roles of nurse managers is to make use of their clinical experience and knowledge to perform effective and autonomous decision making in response to daily clinical situations.[128] In contrast to other nursing staff, nurse managers should possess both the clinical knowledge and management skills to translate healthcare policy into clinical practice.[129] In real clinical settings, the selection of nurse managers is often based on clinical expertise and has been criticized for the inadequate consideration of management potential and educational qualification. The effectiveness of nursing management would be further jeopardized by the ill-structured plans for developing and preparing future nurse managers.

One of the well-known efforts that promote quality nursing care is the Magnet

Recognition Program in the United States.[130] Running since 1980s, the program accredited hospitals with good nursing practice. One of the key organizational attributes of Magnet hospitals was the self-governing unit-level operations where autonomous decision making was supported. Nurses from the Magnet hospitals reported to have greater job satisfaction and perceived to have greater support from nursing administrators who were more accessible and responsive.[131] Fewer patient adverse events such as falls and mortality were reported in Magnet hospitals than in comparable non-Magnet hospitals.[60,132,133]

Front-line nurse managers are in a critical position especially nursing shortage is now a global phenomenon. They are in the best position to retain the workforce by introducing effective retention strategies. In Hong Kong, the problem of nursing shortage was alarming as the turnover rates accelerated and yet the funded educational places remained steady until the late 2000s (Au, 2009). The nurse turnover rate in Hong Kong has increased from 3.2% in 2006/07 to 5.3% in 2010/11.[7] Although the overall number of active nurses in public hospitals increased by 4.6% over the same period, the number of registered nurses decreased in 4 out of 7 specialties (obstetric & gynaecology, orthopaedics & traumatology, paediatrics, and surgery). A previous report showed that support from unit-level managers correlated with job satisfaction and nurses' perceived quality of care.[134] Nurse managers would be able to improve retention by making timely responses to daily challenges and creating a positive work environment.[135]

Table 18. Clinical recommendations regarding supervisory nurse staffing

Source	Specialty	Staffing level	Roles
DoH, UK[33]	Neonatal care	One lead nurse/midwife	Clinical and professional leadership Management of service
BACCN[28,42]	Adult critical care	A senior critical care nurse in unit with more than 6 beds	Oversee the delivery of quality of care Manage staff and patients Communicate with multidisciplinary team members
RCOG, RCMW, RCA, & RCPCH[37]	Delivery and Labor	One whole-time equivalent consultant midwife to 900 low-risk women (who are under midwifery care)	Provide clinical leadership Facilitate evidence-based practice and promote research Provide strategic planning of services Service monitoring
AWOHNN[136]	Perinatal units	Not stated.	Oversee clinical operations Mentor less experienced nurses Patient care assignments
RCP[39]	Psychiatric units	Grade G or H (equivalent to ward manager) with training in ward management	Ward management
PICS[36]	Paediatric intensive care	A 0.5 whole-time equivalent nurse-in-charge per critical bed over 24-hour period over 1 year / 1 nurse-in-charge per shift	Not stated
BAPM[30]	Neonatal care	Neonatal nurse consultant and senior nurses	Neonatal nurse consultant Coordinate education and training Support team members Develop and deliver audit and clinical research projects Senior nurses: Non-clinical responsibilities, e.g. family support, discharge planning, education and practice development, etc. Daily nursing management

AWOHNN, The Association of Women's Health, Obstetric & Neonatal Nursing. BACCN, British Association of Critical Care Nurses. BAPM, British Association of Perinatal Medicine. RCOG, Royal College of Obstetricians and Gynaecologists. DoH UK, Department of Health, the United Kingdom. PICS, Paediatric Intensive Care Society. RCA, Royal College of Anaesthetists. RCMW, Royal College of Midwives. RCP, Royal College of Psychiatrists. RCPCH, Royal College of Paediatrics and Child Health.

5. Recommendations

1. Based on this systematic review, it can be concluded that the nurse-to-patient ratio is a probable key determinant of hospital mortality and a number of nurse-sensitive patient outcomes. In alignment with international service standards, it is recommended that the safe nurse-to-patient ratio in general medical-surgical units be set at 1:4-1:6 during daytime. A higher ratio during daytime should be assigned to critically ill patients (1:2) and pediatric patients (1:4). More nurses should be assigned to patients with higher level of dependency. The proposed recommended ratios should be re-visited regularly. Please refer to Table 16 (pp. 49) for the recommendations in more details.

2. Future planning of staffing requirement should apply a system with transparent algorithms. Determination of nurse-to-patient ratio should also explicitly consider multiple factors such as skill-mix, physical locations and unit size, patient acuity, etc. If the supply of nurses does not meet the projected requirement, phased programs can be introduced. Cautious consideration should be made regarding the employment of agency nurses and pool nurses, especially in ICUs.

3. Training programs for enrolled nurses and registered nurses should be planned in alignment with the projected manpower requirements. The proportion of enrolled nurse graduates has exceeded 30% of the total supply of nurse graduates in recent years. The review suggests that registered nurses are key personnel to contribute to quality of care. The training for enrolled nurses should be treated as a short-term measure in response to nursing shortage. In the long-run, enrolled nurses are highly recommended to undertake conversion programs.

4. Hospital administrators should set up a surveillance system to capture nurse staffing data of each shift as well as patient outcomes. Unit-level data of nurse-to-patient ratio is likely to be more sensitive than hospital-level data to inform hospital administrators on how nurse-to-patient ratio affect patient outcomes, the cost-effectiveness of workforce expansion, and the retention rate. These administrative data are important indicators of service quality and should be regularly reviewed. Advice on the analysis and interpretation of administrative data may be sought from academic nursing leaders.

5. Most of the selected studies in the review were based on Western populations. Very few studies have been conducted in Hong Kong. There is an urgent need to conduct a local study to assess the nurse-to-patient staffing ratios and explore its relationship with quality of care. The data will provide guidance for

policymakers. As mentioned, hospital administrative data provides important source of information. A retrospective study using hospital database can include a large sample and reduces study cost.

6. To allow cross-study comparison, the selection of nurse-sensitive patient indicators should be consistent with the internationally validated measures. Although many of the previous studies have used large national or hospital databases, hospital-level staffing data may not fully reflect the dynamics in individual units. When nurse-to-patient ratios were not directly available from hospital databases, assumptions may be made before the conversion of the staffing data into nurse-to-patient ratios.
7. Safe staffing in psychiatric setting is one of the least investigated areas. Data from other hospital settings are not generalizable to psychiatry setting because of the difference in the outcome measurement of quality care. The research gap has to be filled by further studies that evaluate safe staffing solely within psychiatric units instead of treating psychiatry as one of the general medical units.
8. Supervisory nurses are mainly responsible for overseeing clinical operations, maintaining quality of care, and fostering the development of frontline nurses. However, the staffing level of supervisory nurses has not been adequately explored. The definition of nurse-to-patient ratio usually excludes nurses who do not provide direct care. Evidence to support the roles of supervisory nurses remains anecdotal. Further studies are needed to scientifically quantify their roles and leadership attributes that may promote quality of patient care.

6. Conclusion

While there are a number of systematic reviews on the effects of various nurse staffing measures and quality of care,[51-56] these reviews did not apply meta-analytical techniques and thus the independent relationship between nurse-to-patient ratio and patient outcome could not be quantitatively estimated. The present review comprehensively summarized clinical guidelines that recommended service standards using nurse-patient ratios and studies that investigated staffing ratios with patient outcomes. The use of meta-analysis in this present review has further provided useful information on how staffing ratios affect quality of patient care. The results provided strong evidence in support of using nurse-to-patient ratios in manpower planning. This review also took the first local initiative to propose safe staffing ratios in various clinical settings. More local effort is needed in the future to demonstrate how nurse staffing level contributes to patient outcomes.

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Appendix 1. Data extraction form

Data extraction form

Reference number:	
Author:	
Year:	
Country:	
Study design:	
Sample size:	
Specialty:	
Nurse staffing measurements:	
Outcomes & effect measures:	
Factors adjusted:	
Quality of the study:	