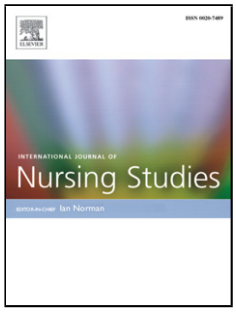

Title: Nurse staffing and patient outcomes: strengths and limitations of the evidence to inform policy and practice. A review and discussion paper based on evidence reviewed for the National Institute for Health and Care Excellence Safe Staffing guideline development

Author: Peter Griffiths Jane Ball Jonathan Drennan Chiara Dall'Ora Jeremy Jones Antonello Maruotti Catherine Pope Alejandra Recio Saucedo Michael Simon

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What is already known?

- A number of high quality reviews establish an association between lower registered nurse staffing levels, increased mortality rates and other adverse outcomes
- Careful analysis of this evidence suggests that it is consistent with a causal relationship
- Translation of this evidence into practice is disputed

What this paper adds

- This paper summarises and extends a recent systematic review on nurse staffing and outcomes undertaken for England's National Institute for Health and Care Excellence
- Methodological limitations mean that existing studies may not give unbiased estimates of the benefits from increased nurse staffing, with over and underestimation of benefit both possible, which makes it difficult to directly translate evidence into guidance for practice.
- We identify avenues for progressing this important research so that future studies might be better able to provide the evidence needed to inform policy and practice, and provide a checklist to aid future study development

Title Page:

Nurse staffing and patient outcomes: strengths and limitations of the evidence to inform policy and practice. A review and discussion paper based on evidence reviewed for the National Institute for Health and Care Excellence Safe Staffing guideline development.

Authors

Peter Griffiths. University of Southampton, National Institute for Health Research Collaboration for Applied Health Research and Care (Wessex)

Room E4015, Building 67, Highfield Campus, Southampton SO17 1BJ ENGLAND

Tel: +44(0)2380597877

Jane Ball. University of Southampton, National Institute for Health Research Collaboration for Applied Health Research and Care (Wessex)

Jonathan Drennan. University of Southampton, Centre for Innovation and Leadership in Health Sciences

Chiara Dall'Ora. University of Southampton, National Institute for Health Research Collaboration for Applied Health Research and Care (Wessex)

Jeremy Jones. University of Southampton, National Institute for Health Research Collaboration for Applied Health Research and Care (Wessex)

Antonello Maruotti. University of Southampton, Centre for Innovation and Leadership in Health Sciences

Catherine Pope, University of Southampton, Centre for Innovation and Leadership in Health Sciences

Alejandra Recio Saucedo. University of Southampton, National Institute for Health Research Collaboration for Applied Health Research and Care (Wessex)

Michael Simon, Inselspital Bern University Hospital, Nursing Research Unit, Bern, Switzerland
Institute of Nursing Science, Faculty of Medicine, University of Basel, Basel, Switzerland

Abstract

A large and increasing number of studies have reported a relationship between low nurse staffing levels and adverse outcomes, including higher mortality rates. Despite the evidence being extensive in size, and having been sometimes described as “compelling” and “overwhelming”, there are limitations that existing studies have not yet been able to address. One result of these weaknesses can be observed in the guidelines on safe staffing in acute hospital wards issued by the influential body that sets standards for the National Health Service in England, the National Institute for Health and Care Excellence (NICE), which concluded there is insufficient good quality evidence available to fully inform practice.

In this paper we explore this apparent contradiction. After summarising the evidence review that informed the NICE guideline on safe staffing and related evidence, we move on to discussing the complex challenges that arise when attempting to apply this evidence to practice. Among these, we introduce the concept of endogeneity, a form of bias in the estimation of causal effects. Although current evidence is broadly consistent with a cause and effect relationship, endogeneity means that estimates of the size of effect, essential for building an economic case, may be biased and in some cases qualitatively wrong. We expand on three limitations that are likely to lead to endogeneity in many previous studies: omitted variables, which refers to the absence of control for variables such as medical staffing and patient case mix; simultaneity, which occurs when the outcome can influence the level of staffing just as staffing influences outcome; and common-method variance, which may be present when both outcomes and staffing levels variables are derived from the same survey.

Thus while current evidence is important and has influenced policy because it illustrates the potential risks and benefits associated with changes in nurse staffing, it may not provide operational solutions. We conclude by posing a series of questions about design and methods for future researchers who intend to further explore this complex relationship between nurse staffing levels and outcomes. These questions are intended to reflect on the potential added value of new research given what is already known, and to encourage those conducting research to take opportunities to produce research that fills gaps in the existing knowledge for practice. By doing this we hope that future studies can better quantify both the benefits and costs of changes in nurse staffing levels and, therefore, serve as a more useful tool for those delivering services.

What is already known?

- A number of high quality reviews establish an association between lower registered nurse staffing levels, increased mortality rates and other adverse outcomes
- Careful analysis of this evidence suggests that it is consistent with a causal relationship
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Nurse staffing and patient outcomes: strengths and limitations of the evidence to inform policy and practice. A discussion paper based on evidence reviewed for the National Institute for Health and Care Excellence Safe Staffing guideline development.

Introduction

Ensuring safe and effective levels of nurse staffing in hospitals is a major concern in many countries. A large and widely cited international body of evidence has linked low nurse staffing levels to higher hospital mortality rates. One of the seminal studies in the field, Aiken's study of 10 184 staff nurses and 232 342 surgical patients in 168 general hospitals in Pennsylvania, USA (Aiken et al., 2002), is among the most highly cited pieces of research about nursing, with 2022 citations on the Scopus research database (August 12, 2015). A systematic review of research confirming the relationship between low nurse staffing levels and adverse patient outcomes found 101 studies published up to 2006, mainly from the USA (Kane et al., 2007). Major studies have continued to be undertaken in countries around the world including Australia (Twigg et al., 2011), China (You et al., 2013), England (Rafferty et al., 2007), Thailand (Sasichay-Akkadechanunt et al., 2003) and across 12 European countries (Aiken et al., 2012, Aiken et al., 2014).

In England, the Francis Inquiry and the Keogh review into care provided by hospital trusts with high death rates identified inadequate nurse staffing as a significant factor associated with poor patient outcomes (Keogh, 2013, The Mid Staffordshire NHS Foundation Trust Inquiry chaired by Robert Francis QC, 2010). As a result of these inquiries, the Department of Health commissioned the National Institute for Health and Social Care Excellence (NICE), an independent body responsible for producing evidence based recommendations to the National Health Service in England, to develop guidance on safe staffing.

NICE applies the principles of evidence based practice to its guideline development process, considering evidence for both the effects and cost effectiveness of its recommendations (National Institute for Health and Care Excellence, 2014). At the start of the guideline development process NICE commissioned a series of evidence reviews on safe staffing from independent researchers. In this paper we consider the evidence that we reviewed for NICE to support its guidance on safe nurse staffing on adult inpatient wards, in order to understand how NICE could have concluded that:

> *"There is a lack of high-quality studies exploring and quantifying the relationship between registered nurse and healthcare assistant staffing levels and skill mix and any outcomes" (National Institute for Health and Care Excellence (NICE), 2014p 27)*,

…while others describe the extensive evidence concerning the association between nurse staffing levels and patient outcomes as "*…compelling"* (Royal College of Nursing, 2010 p.39) and *"…overwhelming…"* (Joint Commission, 2005 p105).

In this paper we consider this evidence in order to understand its strengths and limitations and how these apparently contradictory assessments could be made. We begin by summarising the NICE evidence review and related studies before discussing challenges that arise in interpreting and using the evidence in practice and, in particular, applying it to quantify the benefits and costs of changes in nurse staffing. For brevity we do not cite every included study. Rather we describe overall patterns in the evidence and cite specific examples. We conclude by identifying strategies to increase the usefulness of future research studies for those charged with developing policies and guidance on safe nurse staffing levels.

Review methods and data sources.

The NICE evidence review is described in full elsewhere (Griffiths et al., 2014, Simon et al., 2014). This paper focuses on evidence used to answer two questions specified in the brief by NICE:

1. What patient safety outcomes are associated with nurse and healthcare assistant staffing levels and skill mix?
2. What approaches for identifying required nurse staffing levels and skill mix are effective, and how frequently should they be used?

The term 'effective' highlights NICE's concern to review approaches for identifying required staffing levels, and to consider these as interventions which potentially improve patient and/or staff outcomes or reduce healthcare costs.

We searched for quantitative studies published from 1993 onwards of the association between hospital nurse staffing and a range of patient and nurse outcomes in surgical, medical or mixed (medical-surgical) inpatient settings. Patient outcomes included a wide range of safety related measures (e.g. mortality, falls, pressure ulcers and infections). We

also considered measures of care 'process', such as completeness of care delivery and drug administration errors. Positive measures of patient health such as quality of life were eligible for inclusion but no studies were found. Nurse outcomes included measures of wellbeing and job satisfaction. We searched the CEA registry, CDSR, CENTRAL, CINAHL, DARE, Econlit, Embase, HTA database, Medline including In-Process, NHS EED, HEED, checked references lists in key papers, and hand searched volumes of key journals.

Because the associations between registered nurse (RN) staffing levels and patient outcomes had already been considered in several high quality reviews (e.g. Kane et al., 2007a, Shekelle, 2013), we focussed on those primary studies that considered skill mix or at least controlled for the contribution of the entire ward nursing team (including health care assistants, nursing aides or equivalent). We also limited our review to studies that directly measured nurse staffing on hospital wards and excluded studies that used hospital level nurse staffing estimates (e.g. nurse per patient ratios) rather than ward level staffing. This approach ensured that the evidence presented had the potential to identify the staff groups and combinations of staff contributing to patient outcomes, and to identify ward staffing levels associated with positive outcomes. To supplement this we drew on reviews and seminal studies reflecting the wider evidence base and relaxed the requirements for sources of data in economic studies, which estimated both the costs and consequences of different staffing levels / skill mix, because there were so few of these.

Most of the primary studies that were eligible for the review were cross-sectional. We adapted the NICE quality appraisal checklist for quantitative studies reporting correlations and associations from the methods for development of NICE public health guidance (National Institute for Health and Care Excellence, 2014). Detailed quality assessment considered factors such as the representativeness and completeness of the sample, data completeness, outcome reliability and validity, risk adjustment for outcomes, levels of measurement and analysis methods. We made summative judgements for both internal and external validity, categorising studies according to risk of bias, although these judgements were relative, as risk of bias was intrinsic to most studies due to their design, as discussed in detail below.

Review results

In addition to the existing systematic reviews, we found 35 primary studies addressing our first question about nurse staffing and patient outcomes that met our inclusion criteria, together with an additional four economic studies. A single study addressed the question about effective approaches for identifying required nurse staffing levels and skill mix (Twigg et al., 2011). All the studies we identified were observational. Sample sizes ranged from studies undertaken in hundreds of hospitals (max 636) with millions of patients (max 26684752) to single centre studies and those with less than 1000 patients. Only four studies were assessed as relatively strong for both external and internal validity (He et al., 2013, Patrician et al., 2011, Sales et al., 2008, Spetz et al., 2013). Establishing that presumed cause preceded the presumed effect is a basic requirement for inferring that an observed association between variables is a causal one (Antonakis et al., 2010). However, most studies analysed data in a cross sectional fashion. Generally outcomes over a given period were associated with averaged staffing over the same period. In only six studies was the temporal link between changes in staffing levels and outcomes established, either because one preceded the other or they were measured simultaneously (Ball et al., 2014, Donaldson et al., 2005, Kutney-Lee et al., 2013, Needleman et al., 2011, Patrician et al., 2011, Tschannen et al., 2010) .

Outcomes associated with nurse staffing levels

Mortality

Nine studies in our review reported associations between nurse staffing levels and death rates. Additionally, seven reported associations with failure to rescue (defined as death among surgical patients with complications). Four studies showed significant associations between lower nurse staffing (RN or all nursing staff) and higher rates of death (Blegen et al., 2011, Needleman et al., 2011, Sales et al., 2008, Sochalski et al., 2008). Two studies showed significant associations between lower staffing and higher rates of failure to rescue (Park et al., 2012, Twigg et al., 2013). While results from other studies were not statistically significant (e.g.Kutney-Lee et al., 2013), none showed a statistically significant relationship in the opposite direction.

Based on these findings we concluded that the overall evidence for an association

between nurse staffing and mortality measures was clear, despite the limitations of many studies. The evidence we reviewed is a relatively small proportion of all the available evidence because we included only studies that at least controlled for other nursing staff groups. Other systematic reviews with broader inclusion criteria have reached similar conclusions. For example, Kane and colleagues provided a meta-analysis of 28 studies that reported adjusted odds ratios for the association between nurse staffing levels and a range of adverse outcomes (Kane et al., 2007). In these studies, increased RN staffing was associated with lower hospital related mortality in surgical and medical patients, and failure to rescue in surgical patients. This result was confirmed by a subsequent review of reviews and 15 additional primary studies (Shekelle, 2013).

Other outcomes

Twelve studies in our review reported the association between staffing levels and rates of falls. Three of the twelve found that having more nurses was significantly associated with lower rates of falls (Donaldson et al., 2005, Patrician et al., 2011, Potter et al., 2003). Additionally five studies found the same direction of association but the results were not significant. Four of six studies found that higher nurse staffing levels were significantly associated with shorter length of hospital stay or reduced rates of extended hospital stays (Blegen et al., 2008, Frith et al., 2010, O'Brien-Pallas et al., 2010, Spetz et al., 2013). Kane's meta-analysis concluded that an increase of 1 RN per patient day was associated with a 24% decrease in length of stay for surgical patients (Kane et al., 2007).

Four studies explored associations between "missed care" (that is required nursing care that was not performed in a given time period) and staffing. These studies all relied on nurse reported measures of missed care. Three of these showed significantly more missed care was associated with lower staffing levels (Ball et al., 2014, Tschannen et al., 2010, Weiss et al., 2011).

However, for other outcomes often regarded as nurse sensitive the results are less consistent. For example, 12 studies reported the association between staffing and pressure ulcers. Three found that higher staffing was significantly associated with lower rates of ulcers (Donaldson et al., 2005, Duffield et al., 2011, Hart and Davis, 2011). However, two studies found a significant association in the opposite direction, with units

/ hospitals with more staff having higher rates of pressure ulcers (Cho et al., 2003, Twigg et al., 2013). Nine studies explored associations with drug administration errors of which three showed low staffing to be significantly associated with higher rates of errors (Frith et al., 2012, O'Brien-Pallas et al., 2010, Patrician et al., 2011). One study found that wards with more nursing staff had significantly higher error rates (Blegen and Vaughn, 1998).

Our review included little evidence on outcomes for nurses. This may result from our focus on studies that controlled for other staff groups, which put a relatively large body of evidence outside our scope. None of the six studies that met our inclusion criteria showed significant associations between nurse staffing levels and nurse outcomes, although a number of other studies suggest that there are higher levels of job dissatisfaction and burnout amongst nurses where staffing levels are lower (e.g.Aiken et al., 2002, Aiken et al., 2012).

While the overall pattern of evidence across studies for most outcomes is consistent with a beneficial effect of higher nurse staffing levels for patients, a number of significant results in the opposite direction serve as a useful reminder that it should not be assumed that observed associations necessarily represent a causal effect of variation in staffing levels. This applies as much to results for associations that favour higher staffing levels as it does to those suggesting an adverse effect, such as the studies on pressure ulcers. We return to this issue later in this paper.

Outcomes associated with nursing assistants and skill mix

While most of the evidence reviewed so far suggests that having more nurses on wards is associated with better patient outcomes, this was not the case when we looked at studies that reported on staffing by unregistered assistant nurses or nursing support workers. Eight mostly weak studies gave no strong evidence of beneficial associations between nursing support worker staffing and patient safety. Studies found no association with mortality (Unruh et al., 2007), failure to rescue (Park et al., 2012), length of stay (Unruh et al., 2007), venous thromboembolism (Ibe et al., 2008), or missed care (Ball et al., 2014). However, higher assistant staffing was associated with higher rates of falls (Hart and Davis, 2011, Lake et al., 2010), pressure ulcers (Seago et al., 2006), readmission rates (Weiss et al., 2011), medication errors (Seago et al., 2006), use of physical restraints

(Hart and Davis, 2011) and lower levels of patient satisfaction (Seago et al., 2006), although one weak study found that higher HCA staffing levels were associated with lower rates of pressure ulcers (Ibe et al., 2008).

We also identified 22 studies that reported relationships between skill mix (typically proportions of RNs to the total nursing workforce) and outcomes. A number of these studies found an association between a nursing skill mix that has a higher proportion of RNs and better outcomes including lower mortality / failure to rescue (Blegen et al., 2011, Estabrooks et al., 2005, He et al., 2013), lower rates of infections (Blegen et al., 2011, Cho et al., 2003, McGillis Hall et al., 2004), falls (Blegen and Vaughn, 1998, Donaldson et al., 2005, Duffield et al., 2011, Patrician et al., 2011), pressure ulcers (Blegen et al., 2011, Duffield et al., 2011, Ibe et al., 2008), and higher patient satisfaction (Potter et al., 2003). The overall pattern of results is largely consistent, with the only significant contradictory evidence coming from one of the weaker studies which showed that a higher proportion of registered nurses was associated with a higher nurse reported incidence of pneumonia (Ausserhofer et al., 2013).

We therefore concluded that the evidence provided no support for an association between higher levels of staffing by assistive personal and improved patient safety or nurse outcomes, with some evidence of harm and a strong indication for an association between a skill mix that is richer in RNs and improved outcomes.

Effective approaches for identifying required nurse staffing levels and skill mix

Methods for matching patient need with staffing levels

Only one study included in the NICE review explored the impact on patient outcomes of a method for identifying the required nursing workforce. Twigg and colleagues demonstrated that the introduction of a method that identified required nursing hours per patient day, based on ward specialty and acuity, was associated with significantly reduced adverse patient outcomes including mortality, central nervous system complications, pneumonia and gastrointestinal bleeds on surgical wards (Twigg et al., 2011).

The scope of the NICE review explicitly excluded consideration of the effects of policies setting mandatory minimum nurse to patient ratios on hospital wards. As these could be considered an example of an approach to determining nurse staffing requirements we give a brief summary of evidence here.

Mandatory ratios for general wards have been implemented through legislation in the US state of California and through agreement with employers and trade unions in some states of Australia (South Australia, Victoria). In general these policies dictate a minimum staffing level that varies by the type of ward. At the time of writing this review, legislation is (or has recently been) under consideration in other US and Australian states, Wales and Korea. Benefits claimed for mandatory minimum staffing policies include improved patient and staff outcomes and improved recruitment and retention of nurses, although fears have been expressed that RNs might be displaced by less qualified licensed nursing staff in order to meet mandatory levels at lower cost (National Nursing Research Unit, 2012).

The most widely studied such policy is the California Assembly Bill 394 which mandated minimum nurse to patient ratios (State of California 1999), implemented in 2004. A systematic review of 12 studies exploring the impact of the Californian staffing mandate concluded that there was evidence that the legislation was associated with a reduction in overall nurse workloads and an increase in hours of registered nurse care per patient (Donaldson and Shapiro, 2010). There was no clear evidence for an improvement in nurse sensitive outcomes or quality indicators such as pressure ulcer rates. However, there were a number of historical trends that co-occurred, including increased patient acuity and patient safety initiatives encouraging reporting of adverse events.

One study found a significant decrease in failure to rescue rates in some Californian hospitals (Mark et al., 2012) but the pattern of difference was not clearly linked to staffing increases. The largest (and significant) decreases in failure to rescue were observed in both hospitals with the worst pre legislation staffing (which had the greatest increase in staffing levels) and in hospitals with the highest pre-legislation staffing levels (which had the smallest staffing increase). Similarly Cook et al. (2012) found significant improvements in failure to rescue rates but using an instrumental variable regression found no evidence that this was associated with changes in staffing levels. Spetz et al

(2013) provide modest evidence for the benefits of the policy with hospitals showing the highest growth in staffing following implementation of the staffing mandate associated with decreases in mortality subsequent to a complication (failure to rescue) and lower increases over time in rates of pulmonary embolism / deep vein thrombosis.

Aiken and colleagues compared nurse and patient outcomes in California with two other US hospitals in states without a mandate and found that Californian nurses reported caring for significantly fewer patients per nurse and were much more likely to report favourable working conditions (Aiken et al., 2010).

Beyond evaluations focussing on the implementation of these staffing policies which set fixed minimum staffing levels per ward we found little evidence. Nonetheless there are many workload management systems in use which are designed to quantify nursing activity for staffing purposes (Edwardson and Giovannetti, 1994). Examples of such systems include the Safer Nursing Care Tool (The Shelford group, 2014), widely used in the UK, and many commercially available systems such as GRASP, Medicus System's NPAQ and RAPHAELA. These systems are generally based on analysis of patient profiles (acuity, dependency), critical indicators of care or analysis of time required for documented nursing tasks (Edwardson and Giovannetti, 1994). We identified a recent systematic review that explicitly addressed methods for determining staffing requirements (Fasoli and Haddock, 2010). This review of 58 studies found little objective and validated information regarding any system to determine staffing requirements, a lack of standardization of measures and concluded that systems to determine staffing requirements do not adequately capture nursing work and provide insufficient accuracy for resource allocation or for decision making. Our brief from NICE excluded the direct assessment of the validity of such tools in terms of their accuracy or precision, although robust evidence of effectiveness is the ultimate test of validity and so the conclusion that no method is properly validated seems clear.

In summary it is difficult to make direct conclusions about the impact of mandatory staffing policies because of the complex inter relationship between changes in staffing levels and system wide changes including patient case mix and other safety initiatives. A number of lines of evidence converge to indicate that these policies are effective in increasing staffing levels, which is in turn associated with better patient outcomes.

However, the evidence is not entirely consistent and the extent of the benefit is unclear. Evidence is lacking for other approaches, including the use of tools to match nurse staffing levels to individually assessed patient need.

Economic Evidence

Evidence from four studies (Dall et al., 2009, Needleman et al., 2006, Shamliyan et al., 2009, Twigg et al., 2013), which developed economic models using estimates of benefits derived from other studies, suggests that the costs to the hospital of increased nurse staffing may not be offset by savings from better patient or system outcomes (Table 1). Estimates of the cost per life saved varied hugely between studies. Cost per life saved in studies taking a hospital cost perspective ranged from over $9 million US dollars (Dall et al., 2009) to AU$62,522 (approx. $46,000 US at current exchange rates) (Twigg et al., 2013). While studies that took a wider societal perspective suggest a net economic benefit from lost productivity avoided (Dall et al., 2009, Shamliyan et al., 2009), only one scenario modelled in one study (Needleman et al., 2006) suggested a net cost saving to hospitals from increasing numbers of RNs.

The diverse results and varying methods used in these studies make it hard to draw a clear conclusion although the case for a richer skill mix appears to be stronger. This assessment tallies with a recent extensive review of economic evidence (Twigg et al., 2015). Different answers arise with different cost perspectives.

Discussion

The evidence base for associations between nurse staffing and patient outcomes is exclusively comprised of observational studies. This evidence is broadly consistent with a protective effect for increased nurse staffing in relation to a range of patient safety outcomes, care processes and nurse outcomes. A skill mix that is richer in RNs (as opposed to licensed practical nurses or care assistants) is associated with improved outcomes. Higher levels of care assistant staffing are not associated with improved outcomes. While desired positive changes in nurse staffing levels were achieved though mandatory minimum staffing policies, direct evidence of benefits for patients from these policies is scant, although the Western Australian nursing hours per patient day methodology was associated with an increase in staffing and evidence of improved

outcomes. We found no evidence for the effect of using tools designed to measure the requirement for nursing care at the patient level or any other approach to determine nurse staffing requirements. Economic studies give widely varying estimates of the costs relative to benefits (in terms of lives saved) for increases in nurse staffing. Having described the evidence as a whole, we now move to consider a number of issues that raise challenges for implementing these findings into guidelines for practice.

Economic case

While some of estimates of the cost and consequences of increases in nurse staffing would be unlikely to be judged as cost effective against criteria for judging acceptable cost-effectiveness thresholds in terms of Quality Adjusted Life Years (Claxton et al., 2015), others would compare favourably with the incremental cost effectiveness of widely accepted interventions unless extremely pessimistic assumptions were applied to the length or the quality of the lives saved. This evidence points toward a richer skill mix (proportion of RNs) as the most likely cost effective approach. Studies that considered wider societal benefits (for example, lost productivity averted) indicated a potential for substantial net economic benefit.

Caution is needed when attempting to apply these economic estimates to settings other than those that they were derived from, as the relative costs of different changes in staffing and outcomes are likely to be highly sensitive to underlying cost differences, including the costs of different nursing staff groups and hospital costs for treatment and extended stays related to complications, which are highly variable between different health systems (Goryakin et al., 2011). However, assumptions about costs can be changed, provided the underlying relationships are accurately estimated. But consideration of the economic case raises a more fundamental challenge to interpreting and applying the evidence. Economic models rely on estimates of benefits made using regression coefficients from observational studies. They are thus critically dependent upon the extent to which these coefficients accurately represent the causal effect of changes in staffing levels, rather than simply quantifying associations. If effects are not estimated accurately then the direct application of the evidence to specific staffing decisions, and opportunities for choosing between different strategies for delivering safe and high quality care may be limited.

- Table 1 summary outcome and cost results from economic studies

Study	Intervention	Estimate of Avoided mortality[1]	Estimate of Avoided adverse events	Estimate of Hospital days avoided	Costs Savings	Costs Additional	Net cost	Cost per life saved
Dall (2009)	Increase RN hours to 75th percentile, where required	5,900	NR[2]	3,600,000	6,100[3]	11,039[4]	4,939	$837,119
Needleman (2006)	Option 1 – raise proportion of RN hours to 75th percentile	354	59,938	1,507,493	1,053[5]	811	-242	0
	Option 2 – raise licensed nurse hours to 75th percentile	597	10,813	2,598,315	1,719	7,538	5,819	$9,747,069
	Option 3 – combine option 1 and option 2	942	70,416	4,106,315	2,772	8,488	5,716	$6,067,941
Shamliyan (2009)	Surgical – increase RN staffing by 1 FTE per patient day in this setting	592,958	NR	NR	1,646,190	923,832	-722,358	0
	Medical – increase RN staffing 1 FTE per patient day in this setting	425,568	NR	NR	1,244,061	982,800	-261,261	0
Twigg (2013)	Increased hours with Nurse Hours per Patient Day method	155	709	NR	7,142,466[6]	16,833,392	9,690,926	AU$62,522[7]

1 Estimates of avoided adverse events etc. and associated savings are those reported in the papers and are dependent on the size of the study population
2 Not reported
3 Valued in US dollars, 2005 and presented in million US $... This represents the estimate of reduced medical costs associated with reduced NSO
4 value estimated by this review authors, based on study reported increase of 133,000 FTE RNs at annual cost of $83,000 (salary $57,820 and 30.4% benefits), US $, 2005
5 Costs / savings in million US $. Base year for not reported
6 Costs / saving in AU $. Base year for not reported
7 Est AU$8907 per life year saved

Causal Inference

Although all the studies we reviewed were observational, an assessment against the so called Bradford Hill criteria (Hill, 1965) largely supports the case that nurse staffing is related to mortality in a causal manner, because of the overall consistency of results as shown in meta analyses (e.g. Kane et al., 2007), the invariance of the conclusions to specific features of study design, and features such as dose response relationships (Kane et al., 2007). Needleman's study demonstrates that increased risk of mortality follows after periods where patients are exposed to nurse staffing below that which was deemed necessary (Needleman et al., 2011) confirming the temporal order of events although the observed associations are typically small, making causal conclusions more difficult.

However, while careful epidemiological analyses such as that offered by Kane et al. (2007) support the conclusion that there is a causal relationship, this does not necessarily mean that the estimates of the associations derived from studies are unbiased. In the following sections we explore some specific sources of bias within a framework provided by the concept of endogeneity, derived from the field of econometrics.

Endogeneity

Endogeneity refers to different forms of bias in the estimation of causal effects. It is a potential problem in any observational study and can lead to bias in the estimation of association and hence causal effect (Johnson et al., 2009). While there are several causes of endogeneity (Antonakis et al., 2010) there are some specific patterns of relationship that will predictably lead to endogeneity when assessing the link between staffing and patient outcomes: omitted variables, simultaneity and common-method variance. We address these three below

Omitted variables

Contradictory empirical results from studies may depend on the failure of the adopted statistical models to fit the data due to a failure to include important variables in the model specification. Omitted variable bias results as the omitted variables induce correlation between the outcomes and the error term of a regression model (Antonakis

et al., 2010).

To illustrate the potential effect of missing variables in relationships between nurse staffing levels and outcomes, consider the relationship between nurse staffing and mortality which must, by its nature, be partial and, in most cases, indirect. For example, one of the key mechanisms identified for nurses to contribute to variation in mortality rates is through surveillance, early detection of patients at risk of deterioration and initiating appropriate escalation (Clarke, 2004, Griffiths et al., 2013). Low staffing compromises these activities, but nurses are not the only staff group involved nor is staffing level the only factor affecting the quality of care.

Recognition of deterioration requires not just observation but also appreciation of the significance of the observations. Broadly speaking, the competence of the nurse also plays a significant role, as does the capacity and competence of other actors in the system of response. While studies we reviewed for NICE suggest that a skill mix with more registered nurses is associated with better outcomes, and other studies suggest that a nursing workforce with a higher proportion of nurses educated to Bachelor's degree level is associated with lower mortality, (e.g. Aiken et al., 2014) these measures, are at best, indirect measures of nurse competence.

The role of medical staff in achieving patient outcomes and maintaining safety is largely neglected in the literature on nurse staffing. The few studies that have directly considered medical staffing levels in their analyses point to significant associations between medical staffing levels and mortality (Bond et al., 1999, Griffiths et al., 2013, Jarman et al., 1999, Ozdemir et al., 2016). Thus there is at least one important variable that is missing from most analyses, which has important implications for the accuracy of the associations between nurse staffing and outcomes that are reported.

Unless there is no relationship whatsoever between the omitted variables and the variable of interest (in this case nurse staffing), estimates of effect will be biased. In the case of nurse staffing levels and staffing by other professional groups there tends to be a relatively strong correlation between the two (Griffiths et al., 2013). If studies do not account for medical staffing, an observed association between nurse staffing and patient outcomes could be partly or wholly due to an effect of medical staffing levels.

Competence of nurses and medical staffing are but two examples of variables with known relevance to the causal relationship that is to be estimated if the effect of nurse staffing levels is to be determined without bias. We have not exhaustively catalogued the range of variables that have been modelled alongside nurse staffing levels, either as 'control' variables (not of direct interest to the researchers) or as additional staffing variables that were a focus of interest, but we list a number of examples in figure 1.

Figure 1: Potentially omitted organisational variables in nurse staffing outcome models

- Hospital technology / teaching status (e.g.Aiken et al., 2014)
- Human resource management factors (training, appraisals, teamwork) (West et al., 2002)
- Medical staffing levels (e.g.Bond et al., 1999))
- Registered nurse qualification level / competence (e.g. Aiken et al. (2014))
- Shift patterns / overtime working (e.g. Griffiths et al., 2014)
- Skill mix / care assistant staffing (numerous studies op. cit.)
- The nurse practice environment (e.g. Friese et al. (2008)

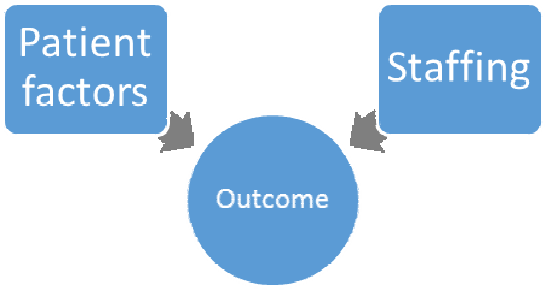
In addition, patient case mix and underlying differences in individual risk clearly affect patient outcomes. Risk models (and hence variables that should be included) are relatively well-developed and validated for mortality based measures (e.g. Aylin et al., 2007, Bottle et al., 2011). However, this is not the case for all patient outcomes and inadequate adjustment for variation in underlying patient risk, omitting important variables, may explain the inconsistent results for some patient outcomes. This is particularly problematic for outcomes that may be more directly influenced by nurse staffing levels than mortality and so, in other respects, hold promise for reducing the problem of omitted variables on the causal path. One such example is pressure ulcers, which may to be less influenced by medical staffing levels but where models for variation in individual risk are underdeveloped and relevant patient variables often omitted.

The apparently contradictory evidence on pressure ulcers can also be used to introduce the second expected source of endogeneity: simultaneity.

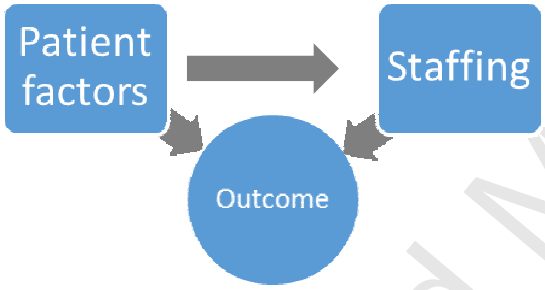
Simultaneity

Figure 2 a b & c. Simplified causal model of staffing outcome relationship

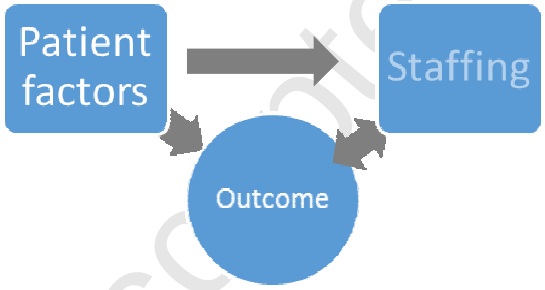
a. Simple model: patient factors and staffing influence outcomes



b. Simple model + patient factors influencing staffing



c. Simple model + patient factors & outcomes influencing staffing



In simple terms, studies examining the association between staffing and outcomes assume a direct causal relationship between staffing levels and outcomes. Obviously, other variables also affect the outcome as noted above. In figure 2 this is simplified and only patient level risk factors and nurse staffing levels are considered. In analysing results from studies, these variables are entered into a regression model and the effect of staffing can be estimated after controlling for variation in outcome caused by variation in patient factors (Figure 2a). However, nurse staffing levels are typically set with regard to patient need and so the same patient factors that influence the outcome may also

influence staffing levels (Figure 2b). As an example, nursing workload tools often estimate required staffing based on measures of patient acuity which, in turn, is influenced by patient factors that influence the outcome. Furthermore, because increase in patient risk is sometimes registered primarily due to increases in adverse outcomes, the outcome itself can causally influence staffing levels at the same time as staffing levels influence the outcome (Figure 2c)

While simultaneity can bias estimates in either direction, it may lead to a systematic underestimate of nurse staffing effects. Wards with more acutely ill patients, with higher mortality risk, may have higher staffing levels to meet patient need. Since these wards will have worse patient outcomes and higher staffing levels before any effect from variation in staffing levels is taken into account, estimates of the effect of nurse staffing derived from regression models may systematically underestimate the true effect.

The effect of nurse staffing can be underestimated to such an extent that it appears to operate in the opposite direction. A number of studies we reviewed, including some of relatively high quality (e.g.Cho et al., 2003), found that hospitals or wards with higher levels of nurse staffing had higher rates of pressure ulcers. That higher levels of nurse staffing should be the cause of the higher rates seems initially implausible (although such explanations should not always be dismissed out of hand). The intuitively more plausible explanation is that patients who are at higher risk of pressure ulcers or, indeed those who have an ulcer, have a higher need for nursing care and it is the variation in staffing levels in response to this that explains the observed association. Thus a (supposed) beneficial effect from increased nurse staffing can still result in a coefficient which indicates the opposite effect.

Studies clearly demonstrating that changes in nurse staffing levels precede a change in outcomes can result in more confident causal inferences (Hill, 1965) and eliminate the extreme issue of simultaneity, although the potential for bias is not completely eliminated, as staffing levels may also respond to changes in patient risk preceding the outcome. If patient risk factors fully predict staffing requirements the problem can be eliminated with careful model specification, as the residual effect of staffing levels after controlling for patient risk is, in effect, the effect of deviation from required staffing. Similarly if nurse staffing requirements are accurately measured and modelled, the effect

of risk on staffing levels can be accounted for. However, accurate prediction of staffing requirements related to patient need is problematic, with limited evidence (Fasoli and Haddock, 2010).

Some of the problems identified above may appear more easily solved when considering nursing processes and outcomes such as burnout and job satisfaction for nurses. However, much of the literature exploring these factors is subject to a third source of endogeneity: common source / common method variance (Antonakis et al., 2010, Chang et al., 2010) .

Common-method variance

Many studies of nurse staffing use one common data source, surveys of nurses, for measuring staffing, work environment variables and outcomes such as job satisfaction and perceived care quality (e.g. Aiken et al., 2002, Aiken et al., 2012, Ball et al., 2014). This can bias effect estimates because respondents to a survey tend to provide answers that are consistent in their point of view, leading to halo effects or effects of social desirability (Antonakis et al., 2010). Adverse reports of the practice environment may be related to reports of adverse outcomes not because one causes the other but because both reflect a global negative response. The extent to which nurse reports of apparently 'objective' matters, such as staffing levels are subject to the same effect is less clear.

Our review for NICE highlighted the promise of measures of necessary nursing care left undone as an indicator of nurse staffing adequacy. While not immune to all the potential sources of bias already discussed, this has a substantial advantage of being the direct result of acts (or omissions) by nurses themselves in most instances. There is a significant body of evidence showing that reports of missed care are increased when staffing levels are lower. However, the current 'state of the art' in measuring missed care (sometimes referred to as implicit rationing or care left undone) relies almost exclusively on nurses' reports (Jones et al., 2015) and so, despite some evidence for the validity of these measures, studies are potentially subject to common method bias. Another frequently studied variable is intention to leave, used as a proxy for nurse turnover. Again there is evidence that the measure is valid, but if independent staffing variables are derived from the same source, there is a risk of bias.

The increasing availability of electronic care records and workforce data open up new possibilities for research which would avoid this bias completely for some areas of interest including missed care. One example where bias could readily be reduced is in the use of measures of leaving intention as a proxy for turnover behaviours. When considering this potential bias, the added value of seeking objective data on actual turnover is much clearer. While it seems unavoidable that some aspects of nurses' experiences and their subjective outcomes must be assessed using a 'common' method and generally a single source, it is important that common method variance is considered and properly accounted for at the design or analysis stage. A range of techniques exists (see for example Antonakis et al., 2010, Chang et al., 2010).

Other Challenges

Leaving aside the potential bias associated with estimates derived from individual studies, a number of questions are not easily answered from the current evidence. For example, should an increase in staffing be applied uniformly across all wards? Will the same benefit be obtained regardless of baseline staffing or the case mix on the ward? For most studies the analysis is, in effect, undertaken at the level of the hospital, even where data is derived from ward based nurses. The resulting coefficients estimate the effect of staffing being the same for all patients (or else large and diverse sub groups) in all hospitals. For a large number of studies the outcomes reported derive from a subgroup of surgical patients, providing a sensitive indicator, while staffing levels are averaged across the whole hospital (e.g. Aiken et al., 2002, Aiken et al., 2014). This evidence can inform broad policy decisions about the possible consequences of change in nurse staffing, but can do little to directly inform deployment decisions for specific wards or patient groups.

In most studies nurse staffing and patient outcomes are collated at hospital level to explore cross sectional associations but the average nurse staffing level gives little indication of the care available and received by an individual patient at a particular moment of time and the relationships that are studied have multiple contributing causes operating at many levels. The allocation of resources relative to patient need will vary by ward, by time of day and by patient, depending on how nursing work is allocated and organised. The interaction between nurses and patients may have important but only

marginal effects relative to the patients' underlying conditions and the acts of other team members. The mechanisms through which nurse staffing can influence outcomes, including missed care, have been hypothesised and a relationship with staffing levels established (e.g.Ball et al., 2014) but the role of these mechanisms in the causal path has rarely been directly demonstrated through studies testing their role as moderators of outcome, although studies are now beginning to explore this. For example Bruyneel et al. (2015) demonstrated how care left undone mediated the relationship between staffing and patient experiences.

The way forward

The literature on nurse staffing has grown substantially in the past 20 years. The evidence generated has been highly influential in a number of countries and is widely cited by policy makers, professional bodies and trade unions. The evidence establishes the potential risks associated with reductions in nurse staffing and shows the potential to benefit from increasing it. However, there are serious limitations in the study designs used. We cannot reliably estimate the cost effectiveness of changes in nurse staffing because we can estimate neither costs nor effects without bias. These biases could result in either over or underestimation of the effects of nurse staffing, or indeed both, depending on the outcomes considered.

This paper highlights why NICE was able to conclude that there was a lack of high quality studies quantifying the relationship between nurse staffing and outcomes. The problem is not a lack of evidence. Nor is it, in absolute terms, about the quality of those studies. Many of the individual studies are strong examples of observational studies. Taken as a whole the pattern of evidence is consistent with benefits arising from improved nurse staffing levels. In this sense, those who describe the evidence as 'overwhelming' also have some basis in fact, although the comment does appear somewhat hyperbolic after closer scrutiny of the evidence. But if evidence is to exert more influence on policy and be more useful to those delivering services it must more directly guide decisions on how many staff are needed which in turn requires that research can give more robust estimates of causal effects.

The programme of work undertaken by NICE was intended to generate guidance for safe

nurse staffing in a range of settings, although initially the guidance focussed on acute hospital care. While some evidence exists about associations between nurse staffing levels and outcomes in other settings; including emergency departments (Recio-Saucedo et al., 2015), nursing homes (Spilsbury et al., 2011), mental health (Bowers and Crowder, 2012), cancer (Griffiths et al., 2013) and primary care (Griffiths et al., 2010, Griffiths et al., 2011, Griffiths et al., 2010); the vast majority of studies are focussed on acute care hospitals. Lack of evidence beyond acute care was cited as one of the reasons that NICE was asked to discontinue its programme of work after completing only two sets of guidance (Lintern, 2015). Consequently this paper has focussed on this evidence. However, while the evidence itself may not generalise the challenges and limitations of the research are the same.

The added value of further cross sectional studies that suffer the same limitations as existing research is relatively low. Rather than simply applying tried and tested approaches, future researchers should look to see what opportunities there are to address some of the challenges we have identified. The 'gold standard' of studies for causal inference – the randomised controlled trial – may not be easily undertaken in this field, but it is by no means theoretically impossible. Further observational research can still contribute much. Technological developments are creating opportunities for far richer data to be accessed to explore the relationships between nurse staffing levels and quality of care. In this regard Needleman's 2011 study stands out because it used shift-by-shift staffing data and established that increases in death followed periods of low staffing (Needleman et al., 2011). The increasing use of electronic records and systems for recording drug administration and vital signs observations makes more direct exploration of the causal pathway between nurse staffing levels and patient outcomes possible.

We propose a series of questions to assess the likely added value of future research. Not all these solutions will be available to all researchers. Those planning studies and those reading research might consider the following points (figure 3). Many of the issues outlined in figure 3 relate to the issue of endogeneity and the problem of obtaining an unbiased estimate of a causal relationship from observational studies. There is a growing literature on analytical approaches to addressing these problems (see Antonakis et al.,

2010). Some of these approaches, for example propensity score analysis or instrumental variables, hold significant promise, but none are without limitations and all require that stringent assumptions are met. It seems unlikely that any single study can completely meet all the requirements for a 'perfect' causal estimate.

So, while statistical methods may help to give estimates that are less likely to be biased it remains incumbent on researchers to recognise that the results of their own models, no matter how well the analysis has been performed, might be biased. Consideration of the possible endogenous relationships allows a discussion of the likely effect of these relationships on the estimate to be discussed and identified, even if they cannot be directly tested. Such discussions are rarely seen in reports of these studies.

Concluding remarks

This paper provides an overview of the evidence base for the association between nurses staffing levels, skill mix and patient outcomes. The evidence is extensive, overwhelming in its size and complexity, but does not provide clear answers. While we conclude that the evidence supports a causal link between nurse staffing levels and patient outcomes in general hospital wards, the evidence is not sufficient to estimate either the costs or consequences of making changes in nurse staffing with any degree of confidence. Consequently the economic case remains uncertain. As ever, we find that more research is needed, and we have provided some guidance to ensure that future work overcomes the limitations of the current evidence base.

Evidence on nurse staffing and patient outcomes has grown remarkably in the past 20 years. It has been instrumental in drawing attention to the important role of nurses in maintaining safety and improving patient outcomes. The evidence available points to a possible economic case for investments in better qualified nurses and a richer skill mix as a focus for improving patient safety in acute care. Despite this, policies currently being considered in many countries, including the UK, contemplate a dilution of skill mix as a potential solution to economic constraints and nurse shortages and authoritative guidance such as that of NICE concludes that the evidence is insufficient to guide staffing decisions. In order to more definitively address these challenges, provide more direct evidence of required staffing levels and build a stronger case for investment, we urge

future researchers to be mindful of the limitations noted here and design future studies so as to minimize the risk of bias.

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Figure 3: Diagnostic questions for added value in staffing outcomes research

- Can the study provide evidence that variation if staffing level *precedes* the outcome?
- Is reverse or simultaneous causation plausible? Has it been considered in the analysis and / or discussed in limitations?
- Are important (patient, person, nurse) characteristics which may influence outcomes considered and included in the analysis
- Are there likely to be other omitted variables?
- Can results be applied to identify staffing required for specific hospital ward types / patient case mix?
- Is there a risk of common method bias?
- Have sensitivity analysis and / or bias assessment been undertaken to explore robustness of estimates?
- Are mechanisms through which nurse staffing can influence outcomes measured and is their role in the causal path tested?

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