Region Västra Götaland, HTA-centrum
Regional activity-based HTA [Verksamhetsbaserad HTA]
Health Technology Assessment
HTA report 2020:118

Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

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VÄSTRA GÖTALANDSREGIONEN
SAHLGRENSKA UNIVERSITETSSJUKHUSET

Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

[Finns det ett samband mellan andelen legitimerade sjuksköterskor (skill-mix) i sjukhusvårdteamet, och patientrisk för död, fallolyckor eller trycksår?]

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Published June 2020
2020:118
Suggested citation: Andersson B, Carlström E, Dahlborg E, Jonsdottir I.H, Sjöland H, Ulin K, Wolf A, Eriksson M, Svanberg T, Petzold M, Sandman L, Svensson M, Wallerstedt SM, Wartenberg C, Sjövall H
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1. Abstract

Shortage of registered nurses has led to changes of staff mix in the health care system. The aim of the current health technology assessment (HTA) was to identify patient risks associated with a reduced skill-mix, here defined as a lower percentage of registered nurses (RNs) versus other staff in the hospital health care team. The question was restricted to patients in general or acute care hospitals open 24/7, excluding hospital outpatient care, primary care, and municipal care. Three adverse medical outcomes were analysed: mortality, falls and pressure ulcers.

Method: Two authors performed searches in February and November 2018 in Medline, Embase, the Cochrane Library, CINAHL, and a number of HTA databases, selected studies, independently assessed abstracts and made a first selection of full-text articles. These articles were sent to all authors and inclusion was decided in consensus. Included articles were critically appraised and data was extracted. The certainty of evidence was assessed using the GRADE approach.

Intervention I1: Lower percentage of registered nurses in the team
Mortality: We found 23 studies containing 48 patient groups assessing variations in the mix of RNs versus other staff**.** All studies were observational, and most were based on register data. The studies were highly heterogenic with regard to country, medical specialty, level of care and method for data analysis. In the included studies the lowest reported skill mix was about 30 % and the highest almost 100%. In 14/48 patient groups, a reduced skill-mix was associated with an increased mortality and in the remaining 34/48 patient groups, no significant association was reported. We did not find any consistent pattern in terms of country, setting, specialty, mode of analysis or study quality between those showing or not showing a statistically significant association. A pooled estimate was not possible to calculate since the step-size (% shift describing the extent of change in skill mix) was generally not stated. The absolute change in mortality was only possible to calculate in four patient groups presented in three studies. Only in one of these studies a significant association was seen, generating a calculated mean mortality increase of 0.14 % /10% decrease in skill-mix. These studies were done in low/middle risk patient groups. In addition, in another study in a high risk population (mean mortality 16%), a 10% shift in skill-mix was associated with an increase in mean mortality of 6 events/1000 cases.

Conclusion: *It is uncertain whether a moderate (-10%) reduction in skill-mix is associated with an increased mortality in patients in general or in acute hospital care (GRADE ⊕◯◯◯).*

Fall risk: There was a similar problem regarding heterogeneity between studies for this outcome. In 9/16 patient groups, a lower skill-mix was associated with a higher risk for falls, while in 7/16 studies, there was no significant association. Calculation of a summary estimate was not possible due to lack of stated step-size for skill-mix. Calculation of absolute risk per unit change in skill-mix was for this reason not possible.

Conclusion: *It is uncertain whether a moderate (-10%) reduction in skill mix is associated with an increased risk for falls in patients in general or acute hospital care (GRADE ⊕◯◯◯).*

Pressure ulcers: There was a similar problem regarding heterogeneity for this outcome. In 8/25 studies, lower skill-mix was associated with an increased risk of pressure ulcers, while the remaining 17/25 showed no significant association. Calculation of a summary risk estimate was not possible since skill-mix step-size was generally not stated. It was also impossible to calculate the absolute risk due to lack of information regarding skill-mix step-size and basal prevalence data.

Conclusion: *It is uncertain whether a moderate (-10%) reduction in skill-mix of registered nurses is associated with an increased risk for pressure ulcers in patients in general or acute hospital care (GRADE ⊕◯◯◯).*

Intervention I2, lower percentage of bachelor nurses in health care team.
In this group, only the outcome mortality was possible to assess, being investigated in one low quality study. Staff included in the denominator was not described and no basal mortality data allowing calculation of absolute effects was provided. aOR for mortality associated with a 10% reduction in skill-mix was 1.09 (1.01 to 1.17), p=0.03.

Conclusion:, *It is uncertain whether a reduced skill-mix (reference: bachelor nurses) is associated with an increased mortality in patients in general or acute hospital care (GRADE ⊕◯◯◯). The association with risks of falls or pressure ulcers has not been studied.*

Concluding remark: This systematic review only found observational studies, mainly data from large registries used for other purposes. The certainty of evidence was very low for all outcomes. We were not able to identify any consistent scientific support for an association between a moderate reduction (-10%) in the proportion of registered nurses (skill mix), and increased risks for the three serious adverse events mortality, falls and pressure ulcers.

2. Svensk populärvetenskaplig sammanfattning – Swedish plain language summary

Brist på sjuksköterskor har framtvingat en förändrad kompetensprofil i sjukhusvårdteamet. Syftet med denna HTA-rapport var att utvärdera om minskad andel legitimerade sjuksköterskor i sjukhusvårdteamet är förenat med ökad patientmortalitet, fallrisk eller risk för liggsår. Frågan fokuserade på patienter i dygnetruntöppen allmän eller akut sjukhusvård, och exkluderade öppen specialiserad sjukhusvård, primärvård och kommunal vård. Utvärderingen gjordes separat för reducerad andel legitimerade sjuksköterskor och för sjuksköterskor med 3-årig universitetsutbildning, så kallade bachelor nurses.

Metod: En systematisk litteratursökning gjordes i februari 2018 och uppdaterat i november 2018 i Medline, Embase, the Cochrane Library, CINAHL och i olika HTA-databaser. Efter en exklusionsprocess kvalitetsgranskades identifierade artiklar med mallar framtagna av SBU och slutsatserna och graden av säkerhet i dessa summerades med användning av det så kallade GRADE-systemet.

Intervention I1: Lägre andel av legitimerade sjuksköterskor, jämfört med övrig personal, i vårdteamet.

För utfallet **patientmortalitet** hittade vi 23 studier baserade på 48 patientgrupper. Alla studierna var observationsstudier och i huvudsak baserade på registerdata. Studierna varierade kraftigt gällande land, medicinsk specialitet, vårdnivå och metod för dataanalys. I de inkluderade studierna låg den lägsta rapporterade skill mixen på cirka 30% och den högsta på nästan 100%. I 14/48 patientgrupper fann man att en lägre andel sjuksköterskor i vårdteamet var förknippat med en ökad patientmortalitet medan man i 34/48 patientgrupper inte fann något statistiskt säkerställt samband. Vi hittade inte något enhetligt mönster vad gällde land, vårdnivå, specialitet, analysmetod eller studiekvalitet som förklarade skillnaderna mellan resultaten i de olika studierna. Den absoluta förändringen i mortalitetsrisk var möjlig att beräkna i sammanlagt fyra patientgrupper från tre studier baserade på en låg/normalrisk population. Bara en av dessa visade ett signifikant samband, med 0.14% mortalitetsökning per 10% reduktion av andelen sjuksköterskor i vårdteamet.
I ytterligare en studie, i en högriskpopulation (16% mortalitet), fann man att en 10%-ig reduktion av skill-mix var förknippad med en ökning i medelmortalitet med 6 promille.

För utfallet **fallrisk** fanns samma problem vad gäller variationer och brister i underlaget. I 9/16 studier fann man att en reduktion av andelen legitimerade sjuksköterskor var förknippat med en ökad fallrisk medan man i resterande sju studier inte fann något statistiskt säkerställt samband. Studierna gick inte att lägga samman eftersom storleken på förändringen i bemanningen inte angavs. Det var inte heller möjligt att beräkna storleken på den absoluta effekten i de få studier som visade en sådan.

För utfallet **trycksår** fanns samma problem vad gäller heterogenicitet. I 8/25 studier sågs en signifikant ökad risk för trycksår vid reducerad andel legitimerade sjuksköterskor, medan man i 17/25 inte fann något signifikant samband. Sammanvägning av studierna var inte möjlig då storleken på bemanningsförändringen inte angavs. Eftersom basalprevalens inte angavs var det omöjligt att beräkna den absoluta effekten.

Intervention I2: Lägre andel sjuksköterskor med 3-årig universitetsutbildning, jämfört med övrig personal, i vårdteamet

Vi fann bara data gällande mortalitet, och detta i en studie av låg kvalitet. Sammansättningen av resten av vårdteamet beskrevs inte och avsaknad av basalmortalitetsdata omöjliggjorde uträkning av absolut risk. aOR for mortalitet associerad med en 10% reduktion av andelen sjuksköterskor i vårdteamet var i studien 1.09 (1.01 to 1.17), p=0.03.

Slutsats: Det är osäkert om en måttlig reduktion av andelen legitimerade sjuksköterskor i sjukhusvårdteamet (-10%) är förknippat med förändring av mortalitet, fallrisk eller risk för trycksår inom allmän och akut sjukhusvård (GRADE ⊕◯◯◯). Samma slutsats gäller för sambandet mellan mortalitet och andelen sjuksköterskor i vårdteamet med 3-årig universitetsutbildning. Övriga aktuella utfall är för denna personalgrupp inte studerade.

The above summaries were written by representatives from the HTA-centrum. The HTA report was approved by the Regional board for quality assurance of activity-based HTA. The abstract is a concise summary of the results of the systematic review. The Swedish summary is a brief summary of the systematic review intended for decision makers, and is ended with a concluding summary.

Christina Bergh, Professor, MD
Head of HTA-centrum of Region Västra Götaland, Sweden, March 25th 2020

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Wallerstedt, Susanna	MD, Professor
Wartenberg, Constanze	Psychologist, PhD

DDS Doctor of dental surgery
MD Medical doctor
PhD Doctor of Philosophy
OD Odontology doctor
PT Physiotherapist
RN Registered Nurse

3. Summary of findings

Outcomes	Study design Number of studies (number of patient groups)	Overall results: significant covariation between variations in skill mix and outcome	Absolute change in outcome associated with a given shift in skill mix	Certainty of evidence GRADE[1]
Mortality (I1: % registered nurses)	Cross sectional: 20(40); Longitudinal: 2(8) Validation: 1(1)	Meta-analysis not possible due to uncertainties regarding step-size. 34/48 patient groups: no significantly increased risk associated with reduced skill mix; 14/48 patient groups: increased mortality with reduced skill-mix	Not possible to calculate in 20/23 studies. Estimated delta mortality/10% reduction in skill-mix: Low/intermediate risk population (four patient groups): +0.14%*, +0.15%, +0.12%, -0.14% High risk population, linear regression (one study): 6/1000 patients.	⊕◯◯◯ [2]
Fall risk (I1)	Cross sectional: 10(10); Longitudinal: 4(4) Pre/post:2(2)	Meta-analysis not possible due to uncertainties regarding step-size. 9/16: increased risk with lower skill mix; 7/16: no significant association	Not possible to calculate due to lack of data regarding basal prevalence of fall risk in studied population	⊕◯◯◯ [2]
Pressure ulcers (I1)	Cross sectional: 18 (18); Longitudinal: 5(5) Pre/post:2(2)	Studies not possible to pool. 8/25: increased risk with lower skill mix; 17/25: no significant association	Not possible to calculate due to lack of data regarding basal prevalence of pressure ulcer in studied population	⊕◯◯◯ [2]
Mortality (I2: % bachelor nurses)	Cross sectional:1(1)	Single study: aOR with reduced skill-mix = 1.09 (1.01 to 1.17), p=0.03	Not possible to calculate due to lack of basal mortality data in studied population.	⊕◯◯◯ [3]
Falls (I2)	No studies found			No studies found
Pressure ulcers (I2)	No studies found			No studies found

Reasons for downgrading:

[1]: Issues regarding directness (e.g. different health system);

[2]: Study limitations (e.g. inappropriate presentation of data, unclear handling of confounders);

[3]: Imprecision (e.g. too few patients, insufficient power)

Certainty of evidence

High certainty ⊕⊕⊕⊕	We are very confident that the true effect lies close to that of the estimate of the effect.
Moderate certainty ⊕⊕⊕◯	We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low certainty ⊕⊕◯◯	Confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect.
Very low certainty ⊕◯◯◯	We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

4. Abbreviations/Acronyms

aOR: adjusted Odds ratio

BN: bachelor nurse

CHF: chronic heart failure

FTR: failure to rescue (high risk patient group with certain diagnoses)

MI: myocardial infarction

O/E: observed over expected Odds ratio

OR: odds ratio

PICO: Patient-Intervention-Comparison-Outcome

RN: registered nurse

SBU: Swedish agency for health technology assessment and assessment of social services

SU: Sahlgrenska University Hospital

5. Background

Problem of interest and its degree of severity: skill-mix in health care

Shortage of health care professionals, in particular registered nurses (RNs), has necessitated new ways of organizing health care. One strategy is to balance a reduced relative number of nurses with increased numbers of other staff categories such as undergraduate nurses/licensed practical nurses ("undersköterskor") and/or nurse aids/assistants ("sjukvårdsbiträden"). This shift is usually described as a **reduced skill-mix**, a definition of skill mix that is also used in the present report. There have been occasional alarm reports indicating that these changes are associated with patient risks, most notably an increased risk of mortality. In many countries and particularly in the United States, the percentage of RNs in the care teams has to be reported to health care registries, resulting in a large body of data enabling assessment of the association between skill-mix and various health outcomes. Evaluating all health care outcomes included in these registries was not considered feasible and we therefore restricted our literature search to three key adverse outcomes: mortality, falls and occurrence of pressure ulcers.

Please note that the concept skill mix has to be distinguished from the concept nurse density at a unit, the latter describing the amount of nursing staff resources with a given competence level available per patient day.

Prevalence and incidence

Basal risk for mortality, falls and pressure ulcers varies markedly between specialties and settings. Averaged data at a Swedish regional level was therefore not considered meaningful to present. Falls and pressure ulcers are also likely to be under-reported to an unknown extent.

Present situation

In Sweden, the care team in general or acute care, i.e. the topic of our PICO, consists mainly of registered nurses (RNs, bachelors or not), undergraduate nurses and nurse aids. In 2016, a total of 108,185 RNs worked in the health care sector, 18,937 of whom were employed in the health care of Region Västra Götaland. The composition of the work team has changed markedly over time, with the aim of increasing the relative numbers of RNs in the care teams. This tendency has occurred in parallel with an upward shift in the academic profile of nurse education. Registered nurses nowadays have an educational and clinical responsibility for the patient regarding some diagnoses, treatments and evaluations that other groups, such as undergraduate nurses, do not have. However, due to shortage of nurses, many units have been forced to reconsider this shift and go back to a lower skill-mix in the team since undergraduate nurses are easier to recruit.

Skill-mix varies markedly between clinical settings, being higher in critical care and lower in e.g. geriatrics/rehabilitation. This report was initiated by the Sahlgrenska University Hospital (SU), therefore we procured current data regarding skill mix-in different types of units (Table 1). There are currently 1,152 RNs, 739 undergraduate nurses and 17 nurse aids permanently employed (Table 1). The proportion varies somewhat depending on type of unit, ranging from 51% RNs in orthopedic wards to 78% RNs in surgery wards).

Table 1. Number of registered nurses (bachelors or not), undergraduate nurses and nurse aids at Sahlgrenska University Hospital (at some selected wards).

Employment	Registered nurses	Undergraduate nurses	Nurse aids	Skill mix (% RNs)
ÖH* Surgery wards	110	60	2	**63%**
ÖH* Medical, geriatric and emergency wards	295	209	8	**55%**
MH** Medical and emergency wards	145	107	0	**56%**
MH**Orthopedic wards	130	122	0	**51%**
SH*** Surgery wards	177	47	0	**78%**
SH*** Medical	295	194	7	**58%**
Totalt	**1 152**	**739**	**17**	

*ÖH= Östra Hospital, **MH= Mölndal Hospital, ***SH= Sahlgrenska Hospital

Nurse training in Sweden

To understand the background to the current situation, one needs to know a little about its history. The first nursing education started in 1851. In line with Civil Affairs Department's report in 1916 (Civildepartementet 1916), a uniform two-year education, with both theoretical and practical training, was established. In the early 1900's, nurse became a protected occupation title in Sweden. In the beginning of the 1950s, the curriculum encompassed three years, including a specialist competence. During the 1960s, we had a shortage of nurses, which can to some extent be compared with today´s situation. The problem led to the creation of the staff category **undergraduate nurse**, and the first regular undergraduate education was started (SOU 1962:4). With this organization strategy, the registered nurse became more of a supervisor or a teacher, while other staff categories mainly carried out "traditional" nursing activities like direct patient care. Since 1958, nursing has become a profession requiring a credential (= **registered nurse, RN**), which guarantees that the holder has the necessary medical knowledge and that their work is consistent with laws, regulations and policy goals. A new nursing education of either five semesters (or three semesters for those who had already acquired a validated hospital practice), started 1966 and uniform education plans were introduced (SOU 1964:45). In 1982, nursing education became a university education and gained a formal academic status, so called **bachelor nurses**. Today, all registered nurses (RNs) undergo a three year undergraduate program including a BSc in nursing, followed by programs or courses at advanced level up to a master level (SFS 1993:100). Specialist training for nurses is an advanced level education lasting between 1-1.5 years, ending with a master degree (M.sc). Legislation behind this structure is The Higher Education Act and The Higher Education Ordinance. In the Act, the foundational goals for all graduate education within the Swedish higher education are stated (SFS 1992:1434).

The development of different educational programs during the past 40 years explains why nurses with different competencies are working within today's health care system in Sweden. Most registered nurses in Sweden have either one of two degrees, the older degree registered nurse, or the more modern degree bachelor in nursing. Many of the nurses with the old type of degree are still active, and the current percentage bachelor nurses in general and acute care is around 60%. This figure will increase with time, since newly graduated nurses will all be BNs.

In Sweden, undergraduate nurses are not included in the system for licensed health care professionals. Their training is a preparatory education in care, given in either high school or in municipal education for adults. After exam, the students are expected to have sufficient knowledge for working in health care settings and in municipal care, in the role of undergraduate nurse (Skolverket 2020). There were almost 140,000 undergraduate nurses in Sweden 2019, 92% of whom were women. This gives an overall skill-mix in the country of 44% (RNs+BNs)/(RNs+BNs+other staff categories).

Current recruitment situation for registered nurses

There is currently a shortage of nurses but the magnitude of this problem varies between regions, settings, specialties and type of care (e.g. the extent of after-hours work). To avoid closure, some units have therefore been forced to reduce skill-mix in wards, resulting in a lower percentage of RNs and a correspondingly higher percentage of undergraduate nurses who are easier to recruit.

Present recommendations from medical societies or health authorities

There are no formal rules regarding optimal skill-mix in hospital care in Sweden. The relative number of RNs and also the percentage of RNs who have a bachelor degree varies geographically and between specialties and settings. The ratio is generally higher in emergency somatic care like intensive care units, and lower in geriatric and rehabilitation care. There are, to our knowledge, no distinct recommendations from authorities regarding the desired proportions of different staff categories at various points in the health care team.

6. Health Tenhnology at issue

Proportion of registered nurses or bachelor nurses versus other staff in the health care team, as related to mortality, fall risk and risk for pressure ulcer in general or acute hospital care.

7. Focused question

In the setting of general or acute care, are reductions of skill-mix (= reduced % registered nurses or bachelor nurses versus other staff in care team) associated with increased risks for mortality or incidence of falls or pressure ulcers?

PICO: P= Patients, I= Intervention, C= Comparison, O=Outcome

P	Patients in general or acute care hospitals open 24/7 (Excluding hospital outpatient care, primary care, and municipal care)
I	Other staff, except for other types of nurses (registered or bachelor)
C	C1 Registered nurse, academic degree not specified C2 Registered nurse, bachelor or higher
O	Mortality Falls Pressure ulcers

Eligibility criteria

Study design:
SR (only commented on – not tabulated)
RCT
Controlled trials (cohort, cross sectional, before and after, time series)

Language:
English, Swedish, Norwegian, Danish

Publication date: 2000-

8. Methods

Systematic literature search (Appendix 1)

During February 2018 two authors (TS, ME) performed systematic searches in Medline, Embase, the Cochrane Library, CINAHL and a number of HTA-databases. During November the same year an updated search was performed. Reference lists of relevant articles were scrutinised for additional references. Search strategies, eligibility criteria and a graphic presentation of the selection process are presented in Appendix 1. These authors conducted the literature searches, selected studies, and independently of one another assessed the obtained abstracts and made a first selection of full-text articles for inclusion or exclusion. Any disagreements were resolved in consensus. The remaining articles were sent to all the participants of the project group. All authors read the articles independently of one another and it was finally decided in a consensus meeting which articles should be included in the assessment. Excluded studies with reasons for exclusion are tabulated in Appendix 3. Included studies have been critically appraised using checklists from the Swedish Agency for Health Technology Assessment and Assessment of Social Services (SBU) and are tabulated in Appendixes 2 and 4.

Ongoing research

A search in Clinicaltrials.gov (2019-05-29) using the search terms "nurse staff" OR "nurse staffing" OR "nursing staffing" OR "RN staff" OR "RN staffing" OR "medical staffing" OR ((nurse OR nurses OR nursing) AND skill-mix) identified 47 trials.
A search in WHO ICTRP (2019-05-29) using the search terms nurse staff OR nurse staffing OR nursing staffing OR RN staff OR RN staffing OR medical staffing OR skill-mix
identified 23 trials.

9. Results

Literature search (Appendix 1)

The literature search identified a total of 2,080 articles after removal of duplicates. After reading the abstracts 1,812 articles were excluded. Another 101 articles were excluded in consensus by two authors after reading the articles in full text.

The remaining 167 articles were sent to all authors, and 44 articles were finally included in the assessment (Appendix 2). The 123 excluded articles are reported with reason for exclusion in Appendix 3. A flowchart of the search results is presented in Appendix 1.

Included studies

This HTA was based on 44 studies, with a cross-sectional (n=34), a longitudinal (n=6), a pre/post (n=3), or a validation (n=1) design. The distribution between outcomes is shown in Table 1. Please note that many studies contained data regarding several outcomes and patient groups, which explains that total numbers sometimes exceed 44.

Table 2: Structure, mode of analysis and quality of identified literature.

Outcome	Mortality			Falls			Decubitus ulcer		
Number of studies	23			16			25		
Number of patient groups	48			17 (no data for 1 group)			29 (no data for four groups)		
Mode of analysis:									
aOR/IRR (%)	20 (44%)			11 (65%)			14 (48%)		
O/E (%)	14 (30%)			0			3 (10%)		
linear regression (%)	3 (7%)			3 (18%)			7 (24%)		
other (%)	9(20%)			3 (18%)			5 (17%)		
Study quality*	**+**	**?**	**-**	**+**	**?**	**-**	**+**	**?**	**-**
Directness	8	4	11	9	1	6	9	2	14
Study limitations/risk of bias	5	3	15	2	4	10	2	4	19
Precision	14	4	5	6	2	8	10	3	12

*+ =no or minor problems; ? =some problems; - = major problems

aOR/IRR= adjusted Odds ratio or incidence rate ratio
O/E= observed over expected Odds ratio

Methodological comments

Heterogeneity was a major problem in the analysis, not only in terms of country, specialty and setting but also, more importantly, regarding mode of analysis. The most common method used was multiple logistic regression, with adjustments for various covariates, generating adjusted odds ratios (aOR) with confidence intervals. By definition, aOR is the change in the dependent variable (e.g. mortality) per step in the independent variable, in this case a given change in proportion of RNs. A major problem with most of the articles was that the step-size used in the calculation (1%, 2%, 5% or 10% change in skill-mix) was generally not stated. It turned out that in some articles, mathematical conversion from assumed 1% steps to 10% steps gave obviously unreasonable values. Therefore, we have refrained from doing meta-analysis on pooled aORs from different studies, and have instead chosen to illustrate the results in Forest plots without summary estimates. It should be observed that with different step-sizes both aOR and confidence interval will change, but whether aOR is significant or not will be unaffected. The same applies to studies using the outcome measure observed over expected events (O/E). To be able to assess all studies, irrespective of mode of analysis and irrespective of step-size, we dichotomized results into those showing or not showing a significant association.

A further methodological problem is that aOR does not give any information regarding the absolute effect (e.g. increased mortality expressed as number of expected cases associated with a given difference in skill-mix). The magnitude of a given shift in the dependent variable will differ depending on the offset point of the shift (e.g. going from 90% to 80% skill mix or from 60% to 50% (Fig 1)).

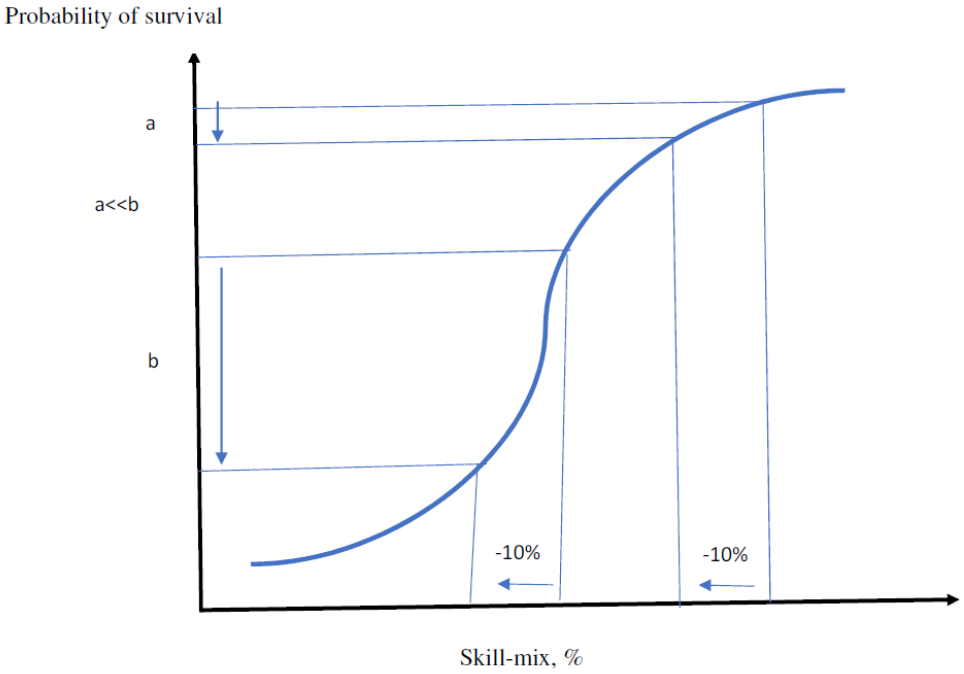

Figure 1: Illustration of problem of conversion of odds into absolute changes. The slope of the underlying probability curve varies with x-axis values (please note that the exact shape of this curve in the current context is unknown, it is only used for illustrative purposes). The slope (delta y/delta x) will depend on basal x-axis values, in this case basal skill-mix. Please also note that this type of sigmoid relationship has to be present to allow the use of Odds ratios at all. The curve will be expected to have its steepest slope around the mean value on the x-axis, e.g. in the mortality case the mean basal mortality in the studied population.

The steepest part of this sigmoid curve usually occurs at the mean value of the independent variable, here mean mortality, mean fall rate or mean pressure ulcer rate. These values vary strongly with setting and patient population, and to be able to convert aOR data into absolute change in mortality risk, one therefore needs information regarding its magnitude in the studied population. This information was generally not available.

The included studies reported levels of skill mix ranging from about 30% to 100%. The applicability and plausibility of the sigmoid model for changes in skill mix at levels below a range commonly considered appropriate for a given patient population is not considered in this HTA.

9.1. Mortality (in hospital or within <30 days)

General comments regarding structure of data:

A major problem with the data was that several different methods were used for analysis. The most common ones were aOR or incidence rate ratio (IRR) (20/48) and O/E OR (14/48 (Table 1). The remaining analyses either used linear regression (3/48), or were based on regressions on timelines or were before-and-after studies (9/48). Quantitative pooling of results obtained with the different methods is not appropriate. The only way of pooling the entire material irrespective of method used was to classify them on the basis of whether there was a significant association or not.

The most common output result was aOR. For illustrative purposes, we constructed Forest plots to illustrate variability between medical specialties, countries, risk stratification and study quality, but refrained from calculating summary estimates due to lack of information regarding step-size on the skill-mix axis. Results obtained in the individual studies are presented in Appendix 4.

Composition of data

For the **mortality** outcome, we identified 23 studies containing data from 48 patient groups regarding comparison C1 (Change of skill-mix with regard to registered nurses, academic degree not specified), and one study regarding comparison C2 (Change of skill-mix with regard to registered nurse, bachelor or higher). The studies had a cross-sectional (n=21), a longitudinal (n=2), or a validation (n=1) design. Most studies were based on register data. **No controlled intervention study was found**. Details regarding the composition of the total data for comparison C1 (country, setting, medical specialty, numbers of hospitals for samplings, number of patients etc) are provided in Table 3. The data consisted of almost 12 million cases, collected from around 7,000 hospitals from US, Europe, East Asia and Australia. The dominating patient category was medicine/surgery/mixed cases.

Table 3: Composition of mortality data, comparison C1

Number of patients, number of wards and hospitals	
Patients	12 037,762
Hospitals	6,683
Number of studies and study types	
Number of studies	23
Study types	
Cross sectional	20
Longitudinal	2
Validation	1
Patient groups and risk stratification	
Involved specialties (n=number of studies)	
Medicine	8
Surgery/trauma	7
Medicine/surgery/mixed	23
ICU/critical care	10
Risk stratification (n=patient groups)	
None	29
High risk group (current or previous ICU/critical care, FTR*)	19
Countries and setting (n= studies)	
Country	
US	11
Canada	3
Europe	2
Far East	1
Australia/NZ	6

*FTR: Failure to rescue

9.1.1. Mortality: other staff versus registered nurses, academic degree not specified

A total of 20 cross-sectional, two longitudinal, and one validation studies fulfilled this PICO (Appendix 4.1.1). In 34/48 patient groups (71%), no significant association between skill-mix and mortality was seen, while in 14/48 groups (29%), lower skill-mix was associated with a significantly increased mortality. 15/23 studies had major study limitations, three studies had some, and five studies had no/minor study limitations. Examples of quality problems were lack of important information such as absolute numbers of deceased patients, inadequate or unclear handling of important confounding factors including nurse density (number of nursing hours/patient and time unit), and insufficient description of the statistics used. For details regarding quality of individual studies, please see Appendix 2, Appendix 4.1.1.and Table 1.

Figure 2 illustrates the proportion of studies in which significant associations between increased mortality and reduced skill-mix were seen (blue bars, n=14), or not seen (red bars, n=34). Data from all included studies with this outcome are shown to the left and that from high quality studies only (defined as studies with none or only some study limitations, n=8) to the right. The pattern was similar, i.e. the majority of studies did not report any significant association between increased mortality and reduced skill-mix.

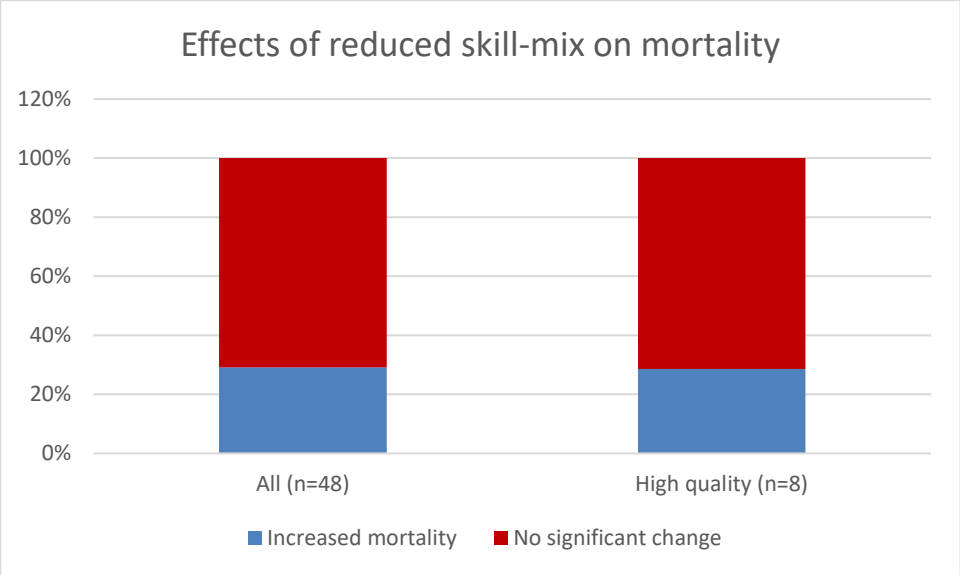

Figure 2: Results in the 23 studies contributing to the comparison *other staff* versus *registered nurses, academic degree not specified* regarding the outcome *mortality*. Data from all patient groups ("All", n=48) are showed in left bars and those from studies with no or only minor problems with study limitations ("High quality", n=8) are shown to the right.

As illustrated in Figure 2, a majority of the included studies did not report any significant association between reduced skill-mix and increased mortality. However, around 30% of the studies did report such an association. A possible mechanism might be sampling error, i.e. that positive studies were performed in different patient groups or were using different methods of analysis. This was explored by comparing the distribution of those features (Figures 3a and b). The positive studies tended to have more high-risk patients (so called FTR, failure-to-rescue-group, see abbreviations) and less of mixed patient groups, but the difference in distribution was not statistically significant. The mode of analysis likewise did not differ consistently between studies with or without a significant association.

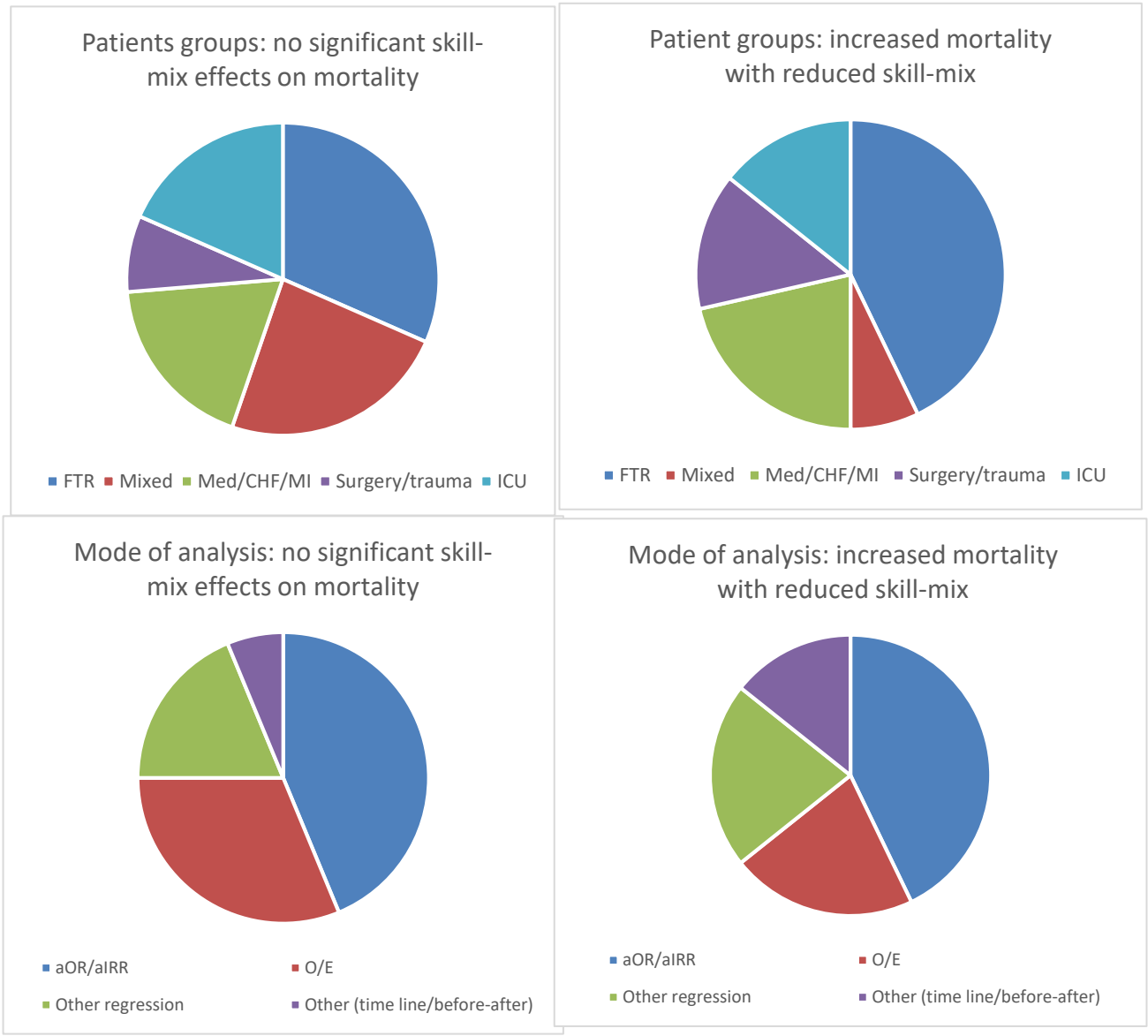

Figure 3: Distribution of patient groups (above, a) and modes of analysis (below, b) in studies showing or not showing a significant association with mortality.

To graphically illustrate the pattern of aOR data in the different studies and settings, we generated a forest plot based on the patient groups for which aOR data were provided. This was done for all studies using aOR, with grouping according to medical specialty, country, patient group and study quality (Fig 4). **Importantly, aORs and confidence intervals are not directly quantitatively comparable since in most studies, step-size for skill-mix was not stated. We therefore refrained from calculating summary estimates.**

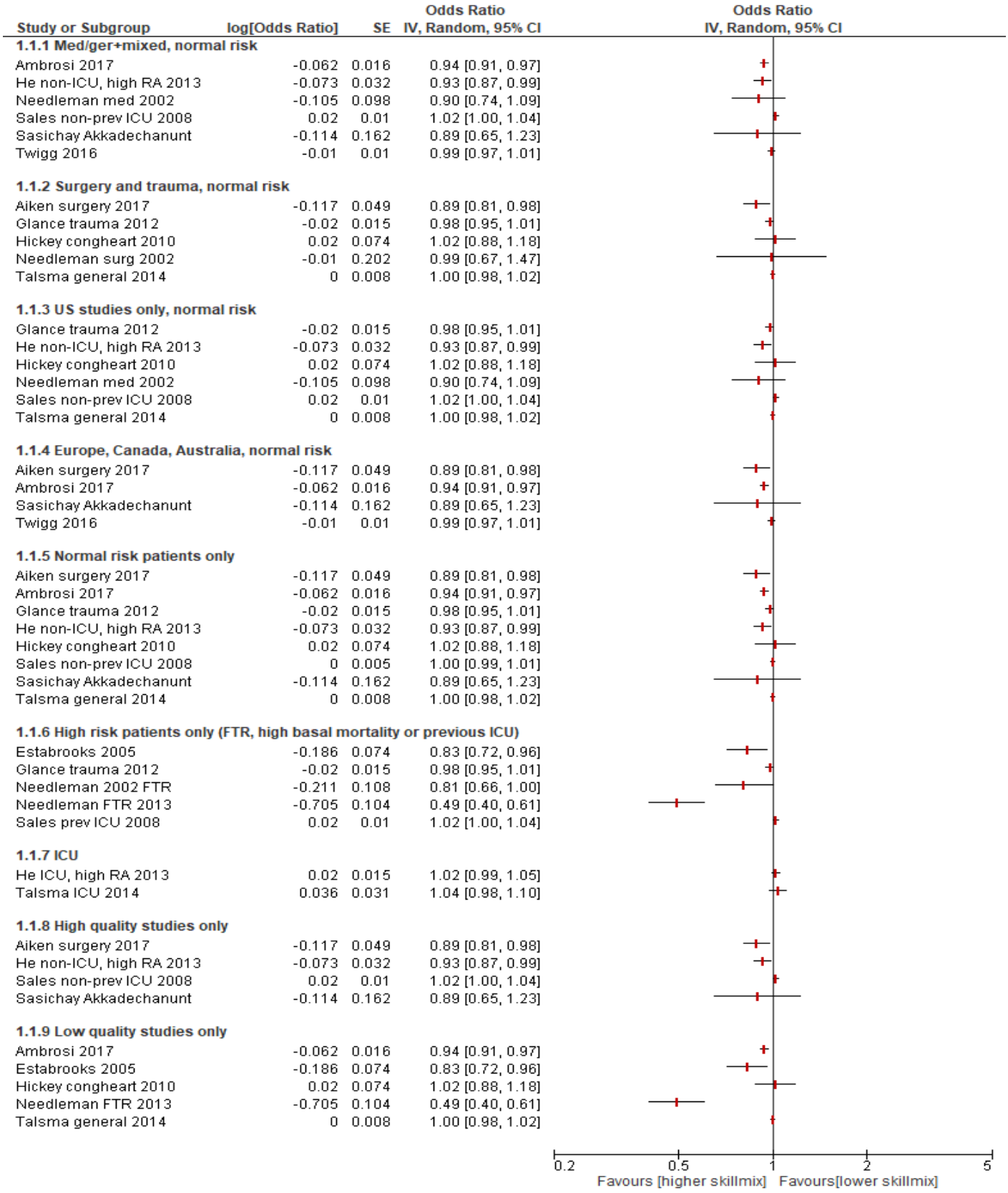

Figure 4: Grouping of aOR data based on medical specialty, setting, countries and patient risk profile. In the figure an aOR below 1 indicates a decreased risk with higher skill-mix. Please also note that some studies appear under several headings. In most studies, the step-size of the % change in skill-mix was not stated, therefore we refrained from calculating summary estimates in subgroups and totally. Please note that some studies appear under several different headings.

An important issue is to determine the clinical relevance of the statistically significant risk increase reported in some studies. The assumption behind using Odds ratio is an underlying sigmoid probability curve, i.e. the result of a given change in skill-mix may vary depending on whether a 10% skill-mix reduction occurs from 90% to 80% or from 60% to 50% (see Figure 1). Usually, the steepest slope of a sigmoid curve occurs at population mean values and we therefore tried to identify those patient groups where mean basal mortality in the population was actually stated. In some of those studies, skill-mix step was also stated, making it possible to convert aOR into 10% steps to allow quantitative comparison. Calculation of the absolute change in mortality rate requires information on the aOR, the step-size of skill-mix in the analysis, and the basal mortality rate. These requirements left three articles containing data from four patient groups (579,358 patients). One study (Aiken 2017) emanated from surgical patients in Europe, one study (He 2013) from Veteran Administration Hospitals (mixed cases and ICU) in the United States, and one (Hickey 2010) was based on children operated for congenital heart disease. The results, recalculated to 10% steps, are shown in Table 4. The association with mortality was statistically significant in the European study (Aiken 2017) and had an absolute magnitude of +0.14%, i.e. 1.4 cases/1000 patients in settings with a 10% lower skill-mix.

Table 4 Studies reporting aOR, basal population mortality rate and skill-mix in stated percentage units on the x-axis in the regression analysis

Study	Outcome measure	n hospitals/patients	Stated step on x-axis	aOR	Population mortality rate	Relative change per 10% decreased skill-mix	Absolute change per 10% decreased skill-mix	Adjusted for nurse density	Study limi-tations
Aiken 2017	aOR	188/275,519	10%	0.89 (0.80 to 0.98)	1.28%	+11%*	+0.14%*	Yes	?
He 2013, non ICU	aOR	128/284,097	10%	0.96 (0.93 to 1.00)	3.77%	+4%	+0.15%	Not clear	+
He 2013, ICU	aOR	128/284,097	10%	0.98 (0.90 to 1.06)	6.30%	+2%	+0.12%	Not clear	+
Hickey 2010, congentia l heart surgery	aOR	38/19,736	5%	1.02 (0.88 to 1.18)	3.56%	-4%	-0.14%	No	-

*P<0.05
aOR = adjusted odds ratio

In addition, we found one study using linear regression (Tourangeau 2007) based on patients with a basal mortality as high as 16.9%. In the text it was stated: “A 10% increase in the proportion of RNs was associated with six fewer deaths for every 1000 discharged patients”, i.e. a mean incremental mortality of 0.6% which is somewhat higher than in the normal-risk patient groups.

Conclusion: *In patients in general or acute hospital care, it is uncertain whether a 10% reduction in skill-mix of registered nurses is associated with an increased mortality (GRADE ⊕◯◯◯).*

9.2.1 Other staff versus registered nurses, bachelor or higher

Only one cross-sectional study fulfilled the PICO C2, i.e a lower skill-mix of RNs with an educational level of bachelor or higher versus other staff (excluding other nurses) (Appendix 4.2.1). This study reported a significant association between reduced skill-mix and increased mortality, aOR =1.09 (1.01 to 1.17). Major problems in directness were found; only 14 of 47 invited hospitals chose to participate, and the nurse density was considerably lower than in Sweden. The study also had major study limitations since nurse density was not considered in the analysis, and the staff included in the denominator was not described. No basal mortality data was presented, i.e. it was not possible to calculate the magnitude of the effect.

Conclusion: *In patients in general or acute hospital care, it is uncertain whether a reduced skill-mix of bachelor nurses as compared to other types of staff is associated with an increased mortality (GRADE ⊕◯◯◯).*

9.3 Falls

Comment regarding structure of data:

For falls, the vast majority of data was expressed as aOR and was therefore illustrated by Forest plots but without summary estimates since skill-mix step-size was generally not stated. The evaluation was based on the proportion of statistically significant or non-significant associations in all identified studies with this outcome.

Results:

For the outcome falls, we identified 16 studies regarding C1 (lower skill-mix of RNs, academic degree not specified), and no studies regarding C2 (lower skill-mix of RNs, bachelor or higher). The studies had a cross-sectional (n=10), longitudinal (n=4), or a pre/post (n=2) design. About 607,000 patients/discharges were analyzed in seven studies. The remaining nine studies did not report the number of patients included. In 9/16 studies, a lower skill-mix was associated with a higher number of falls, while in the remaining 7/16 studies, no significant association was seen (Figure 5). 6/16 studies containing 7 patient groups had no or only minor problems with study limitations. The distribution of significant and non-significant associations in all studies (left) and in high-quality studies (right) is shown in Figure 6. In 9/16 studies results were expressed as aOR. Since the step size of change in skill-mix was generally not stated (exception Aiken 2017: 10%, Everhart 2014: 1% and He 2012: 2%), calculation of a summary estimate was not considered meaningful (figure 6).

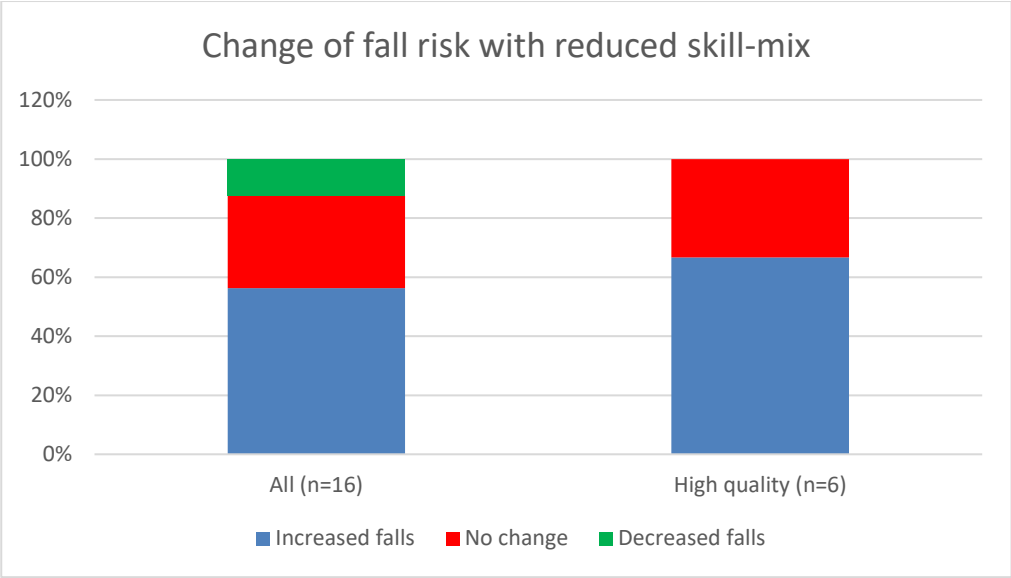

Figure 5. Results in the 16 studies contributing to the comparison *other staff* versus *registered nurses, academic degree not specified* regarding the outcome *falls*, in all and restricted to studies with high quality – ie no or minor problems regarding study limitations (n=6). When results for ≥1 settings were presented in a single study, non-ICU populations were selected for presentation.

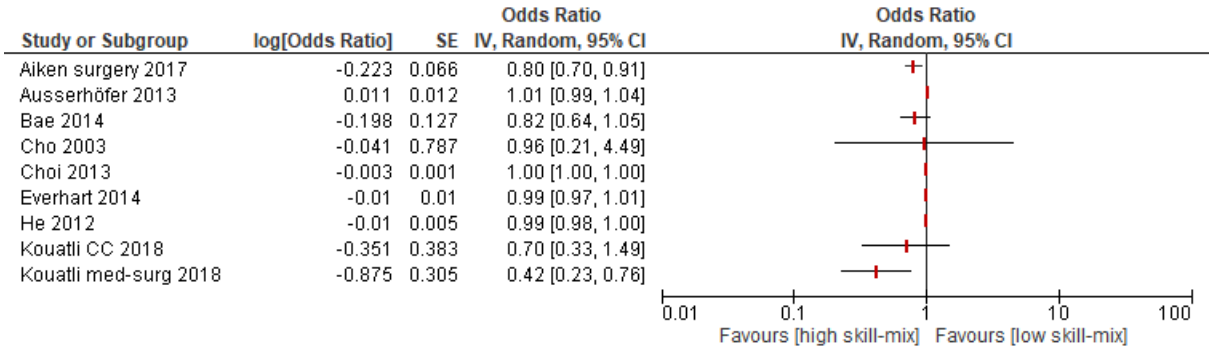

Figure 6: Adjusted OR for falls as related to skill-mix. No summary estimate was calculated since step-size on the x-axis was only stated in three studies (only one of these showed a significant association).

Conclusion: *In patients in general or acute hospital care, it is uncertain whether a 10% reduction in skill mix of registered nurses is associated with an increased risk of falls (GRADE ⊕◯◯◯).*

9.3.1 Other staff versus registered nurses, bachelor or higher

No studies were found regarding this intervention and falls.

9.4 Pressure ulcers

For the outcome pressure ulcers, we identified 25 studies regarding C1 (Reduced skill-mix of Registered nurses, academic degree not specified), and no studies regarding C2 (reduced skill-mix of Registered nurse, bachelor or higher). The studies had a cross-sectional (n=19), a longitudinal (n=5), or a pre/post (n=1) design. More than 21 million patients/discharges were analyzed in 14 studies. The remaining eleven studies did not report the number of patients included. In 8 studies, a higher skill-mix was associated with a lower number of pressure ulcers while the remaining 17 showed no significant association or an increased risk (Figure 7, left).

In all, six out of 25 studies had no or only minor problems regarding study limitations. Only two of those showed an increased risk with reduced skill-mix (Figure 7, right).

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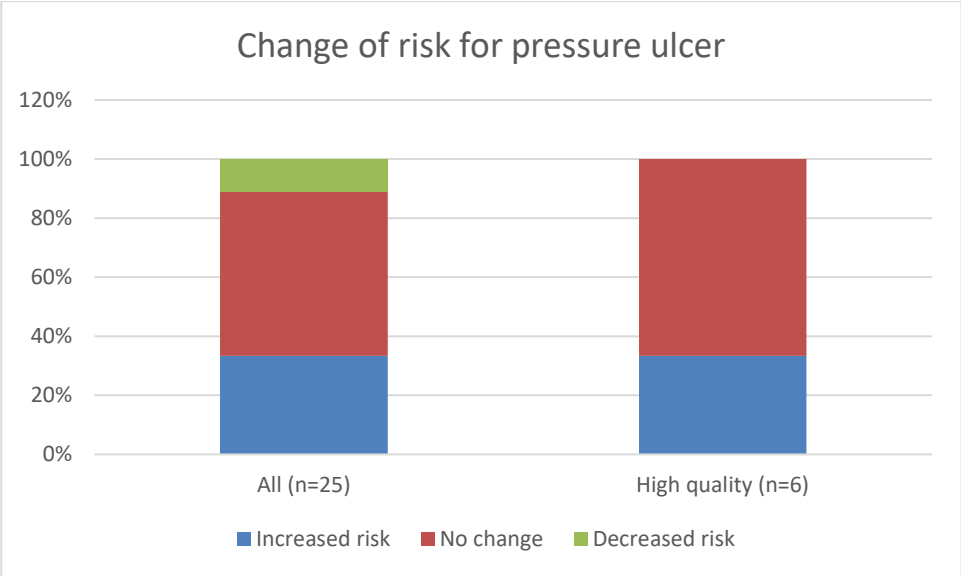

Figure 7 Results in the 25 studies contributing to the comparison *other staff* versus *registered nurses, academic degree not specified* regarding the outcome *pressure ulcers*, in All (n=25) and restricted to studies with high quality – ie no or minor problems regarding study limitations (n=6). When results for ≥1 settings were presented in a single study, non-ICU populations were selected for presentation.

In Figure 8, we plotted data from studies presenting aOR data. For reasons given above (step-size for skill-mix not stated), we refrained from calculating a summary estimate.

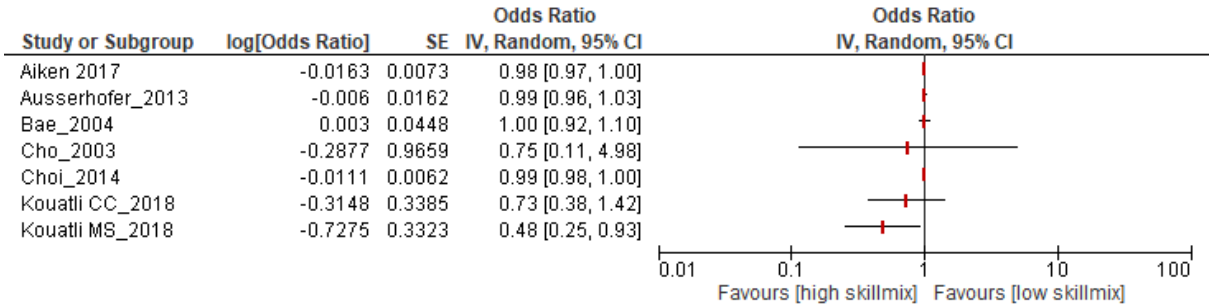

Figure 8 Adjusted OR for the outcome pressure ulcer as related to skill-mix. No summary estimate was calculated since step-size on the x-axis was only stated in three studies (only one of these showed a significant association).

Conclusion: *In patients in general or acute hospital care, it is uncertain whether a 10% reduction in skill-mix of registered nurses is associated with an increased risk for pressure ulcers (GRADE ⊕◯◯◯).*

9.4.1 Other staff versus registered nurses, bachelor or higher

No studies were found regarding this intervention and pressure ulcers.

10. Ethical aspects

The current review did not provide any consistent scientific support for a serious risk of harm associated with a moderate (10%) reduction of skill-mix in the hospital care team. Despite a very large data set, the quality of evidence was considered to be very low. In the case of mortality, an increase (1-6/1000) was observed in some studies. Fully compensating for all other confounding factors like patient characteristics, nurse density, degree of training of doctors and other staff etc is very difficult or maybe impossible and it can therefore not be excluded that the finding of an increased risk was due to unidentified and/or uncompensated confounding factors. For instance, the staffing and skills of physicians/surgeons were not included in any of the analyses, a factor that is likely to affect patient outcome. However, despite the quality issues of the data and the lack of intervention studies, we cannot exclude that such a risk may exist.

The health-care system suffers from a gap between available resources on one hand, and patient needs and expectations on the other. In order to minimise such a gap, different actions are possible: adding new resources to the system; using existing resources in a more effective way; prioritising and disinvesting in or ration care. When handling a resource gap, we need to consider both the short term and long-term perspective and relate potential actions to available alternative actions. One of the scarce resources is professional competence in terms of availability of RNs.

Ideally, RN resources should match the set of patient needs handled within a specific unit. In a long-term perspective, the health care system has reason to achieve such a matching, either by limiting the set of patient needs (often in terms of reducing the set of interventions) to which the staff will cater; or by having long-term strategies for recruiting and maintaining professional competence (or both). In a short-term perspective, these strategies might not be available, and the alternative to a reduced skill-mix might be to close the unit. Generally, a closed unit will not cater to any patient needs, and unless patients are transferred elsewhere, will imply a more radical rationing likely to cause increased morbidity and potentially also mortality in patients. The adverse events caused by closing wards have not been assessed in the current report. Deliberately creating units with a reduced skill-mix for economic reasons has to our knowledge never been advocated and reduced skill-mix should rather be viewed as a measure to temporarily handle resource constraints. In such a situation, it seems wise to also analyse to what extent patient interventions can be prioritised in a way to cater to the more important patient needs, and thereby allow the temporary measure to cause a reduced impact on patient morbidity and mortality. It might also be important to work on short-term and long-term strategies in parallel. However, given the future projections for the resource situation in Swedish health-care – even long-term strategies will have to take into consideration delimitations of which patient-needs the system will be able to meet.

11. Organisational aspects

Present use of the technology in other hospitals in Region Västra Götaland

Shifts in skill mix in acute or general care are continuously going on to adapt to the current difficulties in recruiting RNs. Since the “optimal” skill-mix varies strongly between different settings and medical specialties, the magnitude of this shift at group level is difficult to predict.

Consequences of the new health technology for personnel

Shifts in skill-mix obviously put strains on an organisation, and may sometimes raise concerns regarding patient safety. On the other hand, the Swedish legislation leaves a large room for delegation of tasks normally performed by RNs. Delegation may also leave room for the core tasks of RNs, i.e. leading the health care professionals working in a ward.

The initial intention was to include effects of skill mix change on staff satisfaction in the analysis, however the scope of the HTA had to be restricted for feasibility reasons.

It should also be mentioned that the shortage of personnel is not restricted to RNs. The potential shift towards more nursing staff like assistant nurses and licensed practical nurses will also take time and will likely draw resources due to needs for education. The proposed transformation into "nära vård" in Sweden from hospital-based toward a continuum of care will hopefully also impact the ability to recruit and keep staff within the hospital setting.

Consequences for other clinics or supporting functions at the hospital or in the Region Västra Götaland

The extent of ongoing skill-mix shifts secondary to lack of RNs probably varies markedly between setting and specialties within Region Västra Götaland. The magnitude of this phenomenon will change over time and will vary between settings, and is therefore hard to quantify.

12. Economic aspects

It is important to remember that we did not find any controlled intervention studies, i.e. the topic studied was the association between a lower skill mix and key health outcomes. The driving force behind changes in skill mix is generally **not** economy but handling of a factual shortage of registered/bachelor nurses.

Present costs of labor categories

The mean monthly cost per employee is the sum of the gross wage plus social fees and mandatory retirement contributions. Cost data from 2018 for registered nurses (RN) and nursing assistants (NA, "undersköterskor") were (including social expenses):

- Registered nurse: 48,000 SEK per month
- Nursing assistant: 37,500 SEK per month

At the Sahlgrenska University Hospital (SU), there are about 4,400 RNs and 3,150 NAs and in the Västra Götaland Region there are in total about 10,800 RNs and 6,900 NAs. The annual cost for full time employment of these numbers of RNs and NAs at SU sums up to about 3.9 billion SEK and in VGR sums up to about 6.4 billion SEK.

Total change in costs

Assuming that a reduction in skill-mix is not accompanied by a reduction in the total hours of care per patient, a 10% reduction in skill mix will make it financially possible to hire 12.7% more NAs.

Available economic evaluations or cost advantages/disadvantages

No economic evaluations or cost-consequence or budget-impact analysis studies of changes in skill-mix were identified in the published literature.

13. Discussion

Summary of main results

It is important to remember that reducing skill-mix is generally not a desired option, it is the result of lack of RNs. Not surprisingly, our literature search did not identify any intervention studies and we therefore cannot draw any conclusions regarding causality.

With this reservation in mind, the current review does not provide any clear scientific support for a consistent association between a modest reduction (example case -10%) in skill-mix and increased risks for serious adverse events like mortality, falls and pressure ulcer, at least within the range of skill mix studied. Despite a cumulated amount of data from more than 20 million cases, the scientific evidence was assessed to be very weak. For mortality, an increase in mortality risk was reported in only 14/48 patient groups, without any consistent pattern explaining association or lack of association. Similarly, for falls, 9/16 studies found an increased risk and 7/16 no significant change. For pressure ulcers, 7/25 studies found an increased risk and 18/25 found no significant association.

Grading of these studies is difficult. Since they are all observational and based on register data containing multiple confounders, the reliability depends strongly on how well those confounders were corrected for. One important confounder that was often neglected was nurse density (measured as nursing hours/patient and day), a value that was frequently not stated. Most studies also lacked statements about the step-size (x-axis resolution) of skill-mix used in the regression analysis, which made quantitative interpretation impossible. In addition, as mentioned before, the staffing and skills of physicians/surgeons were not included in any of the analyses. Finally, to translate aOR into absolute risk, the prevalence of the outcome in the relevant population has to be provided, and this information was only rarely given. All of these problems motivate downgrading from GRADE ⊕⊕◯◯ (offset grading of observational studies) to GRADE ⊕◯◯◯, despite data from more than 20 million patients.

In large and well-conducted observational studies, it is possible to upgrade if the effect is consistent and very large. However, in many studies there was no significant association between skill-mix and outcomes while in other studies, a small effect was seen. We therefore cannot feel confident regarding neither the existence nor the size of an association or no association, and upgrading for effect size is therefore not reasonable. We consequently decided on GRADE ⊕◯◯◯ for all three outcomes. Normally, GRADE ⊕◯◯◯ implies that one has no idea regarding neither existence, magnitude nor direction of a putative effect, but in this case more information is clearly available as summarised in the results section.

Overall completeness and applicability of evidence

A major problem with the included studies is that we found no controlled intervention studies. Most data stems from health care quality reports from the United States, where skill-mix is one of several variables. In many studies, attempts have been made to correct for important confounders such as type of disease and nurse density, but still the contribution of the skill-mix factor in relation to very large “background noise” was often hard to evaluate. This problem is particularly large regarding the nurse density factor, i.e. the number of nurses per patient day, a factor that varied markedly both between and within settings. Furthermore, physician/surgeon staffing and skills were not considered in any study, a factor which can be expected to be of importance for patient outcome.

A second major issue is related to different modes of data analysis. Most studies use ORs but if basal prevalence data is not stated, conversion of relative data into absolute data becomes impossible. Even with this information available, one has to remember that the underlying relation between skill-mix and outcome is probably sigmoid, i.e. the effects of a 10% change will differ depending on the basal skill-mix level (e-g- from 90 to 80% or from 50 to 40%). Furthermore, raw data (i.e for example number of deaths/number of patients at different skill mix levels) were rarely provided. It was also in many cases impossible to understand exactly how patient outcomes were related to skill-mix sampling, and sometimes even the level at which skill-mix was determined (hospital/ward/both) was unclear. Taken together, these problems raise serious concerns regarding the interpretation of this very large amount of patient data.

A third source of concern is related to different systems for training of nurses in different countries. As stated in the introduction, nurses in Sweden are nowadays trained at a bachelor level but this is not always the case in other countries.

On the other hand, also in Sweden many experienced older nurses lack a bachelor degree. We found almost no data regarding effects of skill-mix changes in bachelor-nurse-only settings.

Agreements and disagreements with other studies and reviews

The literature regarding effects of skill-mix, in particular the possible mortality signal, is conflicting and the positive studies are much more often cited than the negative ones. The shortage of RNs seems to be global, and the possible mortality signal has been used as an argument for resource reallocation. A recent review from the Swedisch National Health Agency (Socialstyrelsen) concluded that there was an association between reduced skill mix and increased adverse outcomes including mortality, falls and pressure ulcers (Socialstyrelsen 2018). However, this report did not contain any flow chart describing literature search, no data regarding the exclusion process and did not identify all the studies on which our report was based. Moreover, they did not clearly distinguish the factor number of nurses per patient day ("nurse density") and skill-mix. Finally, they did not try to quantify the magnitude of a putative effect.

Concluding remarks

The heterogeneity of the included studies together with incomplete or complete lack of raw data in the studies as well as the lack of controlled trials makes the interpretation of evidence extremely challenging. A risk for mortality may exist in some settings and patient populations, but the incremental risk was in our systematic review found to be low, at least in the low/intermediate risk populations in which the majority of identified studies have been performed. It should also be remembered that the alternative to reducing skill-mix might be to close the unit, an option that also generates patient risks.

Implications for research

Intervention studies and better modes of analysis and presentation of data is desperately needed in this controversial area.

14.Future perspectives

Scientific knowledge gaps

Intervention studies, preferably randomised, are needed. There is also a need for editors to promote increased transparency of the data analysis, for instance by inclusion of original data in published papers to allow interpretation of results in quantitative terms (absolute change).

In this HTA, we did not address important outcomes like patient and staff satisfaction. Several studies addressing these aspects have been conducted, using both quantitative and qualitative approach. In view of the complexity of this issue a separate HTA seems warranted to properly address these important aspects.

Ongoing research

The search in Clinicaltrials.gov (2019-05-29) identified 47 trials, and the search in WHO ICTRP (2019-05-29) 23 trials.

None of the protocols clearly distinguished nurse density and skill-mix. None of these trials were therefore considered to be of key relevance to our skill-mix focused PICO.

15. Participants in the project

The question was nominated by

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Participating healthcare professionals

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Elisabeth Dahlborg-Lyckhage, RN, professor in Caring science, associated professor in pedagogics. Department of Health Sciences, University West, Gothenburg, Sweden

Ingibjörg Jonsdottir, professor, director, Region Västra Götaland, Institute of Stress Medicine, Gothenburg, Sweden

Helen Sjöland, PhD, consultant, Region Västra Götaland, Sahlgrenska University Hospital/Östra Dept. of Anesthesiology and Intensive care, Gothenburg, Sweden

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Declaration of interests

None declared.

Project time

The HTA was accomplished during the period of 30 November 2017 – 24 June 2020
Literature searches were made on February 23 2018, updated November 29 2018.

Appendix 1: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Question(s) at issue:
In the setting of general or acute care hospitals, is mortality or incidence of falls or pressure ulcers associated with reductions of skill-mix (= % registered nurses or bachelor nurses versus other staff in care team)?

PICO: (*P=Patient I=Intervention C=Comparison O=Outcome*)

P	Patients in general or acute care hospitals open 24/7 (Excluding hospital outpatient care, primary care, and municipal care)
I	Other staff, except for other type of nurses (registered or bachelor)
C	C1 Registered nurse, academic degree not specified C2 Registered nurse, bachelor or higher
O	Mortality Falls Pressure ulcers

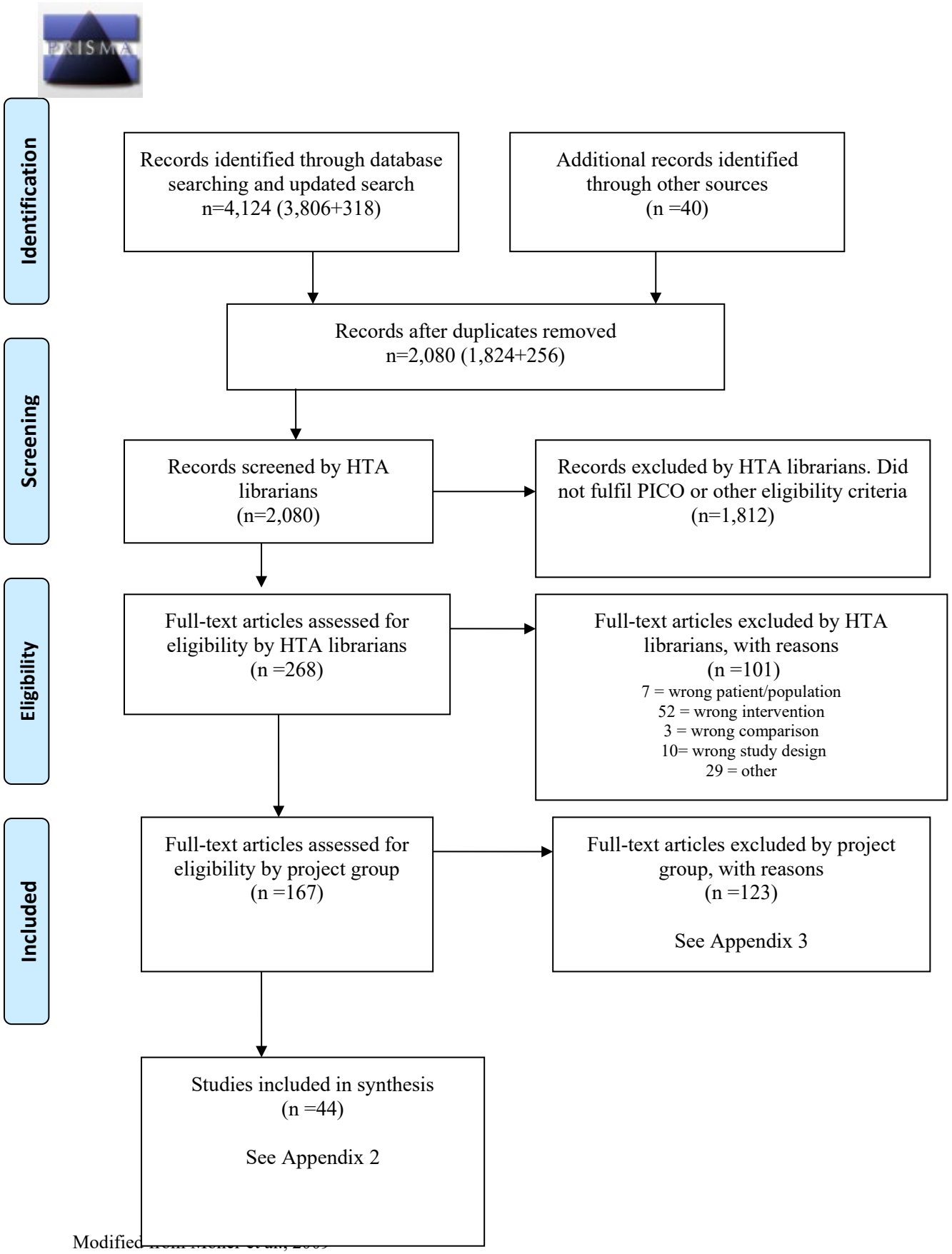
Eligibility criteria

Study design:
SR (only commented on – not tabulated)
RCT
Controlled trials (cohort, cross sectional, before and after)
Qualitative studies regarding patient or staff satisfaction

Language:
English, Swedish, Norwegian, Danish

Publication date: 2000-

Selection process – flow diagram



Modified from Moher et al, 2009

Search strategies

Database: Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to Present
Date: 2018-02-23
No of results: 1389
Search updated: 2018-11-29, 100 results

#	Searches	Results
1	(nurse staff or nurse staffing or nursing staffing or RN staff or RN staffing or medical staffing).ab,ti.	1792
2	(nurs$ and skill mix).ab,ti.	519
3	1 or 2	2198
4	(home or homes or residential).ti.	75210
5	3 not 4	2030
6	limit 5 to (yr="2000 -Current" and (danish or english or icelandic or norwegian or swedish))	1455
7	(letter or comment or editorial).pt.	1608848
8	**6 not 7**	**1389**

Database: Embase 1974 to 2017 January 09 (OvidSP)
Date: 2018-02-23
No of results: 1321
Search updated: 2018-11-29, 78 results

#	Searches	Results
1	(nurse staff or nurse staffing or nursing staffing or RN staff or RN staffing or medical staffing).ab,ti.	2019
2	(nurs$ and skill mix).ab,ti.	531
3	1 or 2	2435
4	(home or homes or residential).ti.	87376
5	3 not 4	2264
6	limit 5 to ((danish or english or icelandic or norwegian or swedish) and yr="2000 -Current")	1660
7	(editorial or letter).pt.	1558486
8	6 not 7	1614
9	**limit 8 to (article or conference paper or note or "review")**	**1321**

Database: CINAHL (EBSCOhost)
Date: 2018-02-23
No of results: 1039
Search updated: 2018-11-29, 110 results

#	Undran	Resultat
S6	**S3 NOT S4** **Avgränsare - Publiceringsdatum: 20000101-20180631; Språk: Danish, English, Norwegian, Swedish ; Akademiska tidskrifter**	**1,039**
S5	S3 NOT S4	2,229
S4	TI home OR homes OR residential	47,322
S3	S1 OR S2	2,396
S2	TI (nurs* AND "skill mix") OR AB (nurs* AND "skill mix")	517
S1	TI ("nurse staff" or "nurse staffing" or "nursing staffing" or "RN staff" or "RN staffing" or "medical staffing") OR AB ("nurse staff" or "nurse staffing" or "nursing staffing" or "RN staff" or "RN staffing" or "medical staffing")	1,994

Database: The Cochrane Library
Date: 2018-02-26
No of results: 57
Cochrane reviews 4
Other reviews 4
Technology assessments 4
Economic evaluations 4
Clinical trials 39
Methods studies 2
Search updated: 2018-11-29, 30 results

ID	Search	Hits
#1	nurse staff or "nurse staffing" or "nursing staffing" or "RN staff" or "RN staffing" or "medical staffing":ti,ab,kw	43
#2	nurs* and (skill mix):ti,ab,kw	25
#3	**#1 or #2 Publication Year from 2000 to 2018**	**57**

The web-sites of SBU and Folkehelseinstituttet were visited 2018-02-26.
Nothing relevant to the question at issue was found

Reference lists
A comprehensive review of reference lists brought 40 new records

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Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Aiken 2017 Belgium England Finland Ireland Spain Switzerland	Cross-sectional	• Acute care hospitals (n=182 to 243 in different outcomes), • University and other hospitals • Analysis at hospital level Discharged adult patients with general, orthopaedic or vascular surgery (≥50 years)	0.66 (range: 0.41-0.87) (RN/all nursing personnel)	6.1/25 (Number of nurses/25 patients)	46.8% (SD: 26.3%) (percentage of all professional nurses with Bachelor degree)	• 275,519 patient discharges • 13,077 Nurse survey responses 18,828 patient survey responses	Mortality AE Patient satisfaction Staff satisfaction Nurse reported falls Nurse reported pressure ulcers
Ambrosi 2017 Italy	Cross-sectional	Acute medical	Not stated RN/(RN+AN)	Not stated. No difference in total care but slightly more NA in deceased group.	Not stated	12 hospitals, 2080 patients	Mortality
Ausserhofer 2013 Switzerland	Cross-sectional	Acute care hospitals (N=35) -University hospitals (n=4) -Center care hospitals (n=15) -Primary care hospitals (n=16) Adult patients from medical, surgical and mixed medical–surgical units	Skill mix; % of nonregistered nurses of the total number of nurses during their most recent shift	Not stated	Not stated	35 hospitals 132 nursing units 1459 patients	nurse-reported adverse events (medication errors, patient falls, pressure ulcers and healthcare-associated infections) Patient satisfaction
Bae 2014	Cross sectional	Not stated	79.5% RNs/(RNs+LPNs+	8.23 nursing hours/patient day	Not stated	3 hospitals	Falls Pressure ulcer

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US			UAPs)			35 nursing units	
Blegen 2011 US	Cross sectional	University health consortium, safety net and non-safety net hospitals Adult general Adult ICU	60+/-7% 76+/-6% %RN/(RN+LPN+NA)	Hours/PPD 11.3+/-1.9 20.8 +/-3.1		54 hospitals 872 wards 1100000 patients	in hospital mortality, decubitus ulcer, failure to rescue, infection due to medical care, postoperative sepsis, >LOS
Blegen 2013 US	Cross sectional	 General adult General ICU	 General: 63+/-6% ICU: 77+/-6% RN mix = RNs/total staff	HPPD 11.6+/-1.6 21.7+/-2.8	61.6%	21 hospitals 84 units	LOS > expected, adverse events (CHF mortality, pressure ulcer, failure to rescue, infection due to medical care, postoperative DVT)
Boonpracom 2018 Thailand	Cross-sectional	Nine regional medical centres	68+/-7%	Patient to nurses ratio 11.8+7-2	Skill mix 52.00-83.00 (mean 68.02)	121 units 819 nurses 840 patients	UTI Pressure ulcer Patient satisfaction

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Burnes Bolton 2007 US	Timeline (pre-post)	Mixed hospitals Medical-surgical Step down	 59-67% 69-74%	(HPPD) 8.1 to 9.1 9.6-10.5	59-74%	64 medical-surgical hospitals 44 step-down 187 units	patient falls, pressure ulcer, restraints
Cho 2003 US	Cross sectional	Acute care hospitals (teaching and non-teaching), surgery-related diagnosis groups	71% "RN proportion": RN hours/all hours	Not in analysis; "RN hours": 6.3 h/patient day	Nott stated	232 hospitals 124204 patients	Falls/injury, pressure ulcer, adverse drug event, pneumonia, UTI, wound infection, sepsis
Cho 2015 South Korea	Cross-sectional	Acute hospitals, metropolitan and non-metropolitan, randomly selected. Surgical discharges.	58+/-26% % BN nurses/(BNs+college level nurses)	Not in analysis; 11.4 pat/nurse	58+/-26% % BN nurses/(BNs+college level nurses)	14 hospitals, 76,036 patients (surgical discharges)	30 day mortality
Choi 2013 USA	Cross-sectional	National registry data Medical (708) Surgical(537) Magnet hospitals(944) Step-down (574)	 %RNs/all nursing staff	Not in analysis; 8.9 h/patient day	71% %BNs/RNs;	2763 units, 576 hospitals, 63034 nurses	Fall rate Job satisfaction

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

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Choi 2014 USA	Cross-sectional	National database, 409 acute care hospitals (Hospital Size Teaching Status Magnet status)	74% (68-90%) RN/(RN+LPN+UAP);	In analysis; 8.57(4.22) h/patient day	Absolute values not stated % bachelor nurses	409 hospitals 2397 units Critical care: 558 Med-surg: 653 Med: 441 Surg: 339 Step-down; 406	Unit acquired pressure ulcers
Donaldsson 2005 USA	Pre/post	"Convenience sample" of CalNOC hospitals (type of hospitals not clearly stated)	Med-Surg: 59±12% (pre); 67±11% (post) Step-down: 69±15% (pre); 72±13% (post) %RN/(RN+LVN+ other contracted) (mean±SD)	NA; (h/patient day) Med-Surg: 8.08 (pre); 8.68 (post) Step down: 9.59 (pre); 10.11 (post)	Not stated	Med-Surg): 28 hospitals Step-down); not stated Med-surg: 200 units Step-down: 68 units	Patient falls incidence Hospital acquired pressure ulcer prevalence Restraints

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

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Duffield 2011 Australia	Longitudinal/cross sectional	Australian public hospital system Medical/surgical/general wards	68%, (45-100%) Medical: 65% Surgical: 69% General: 70% RN/(RN+EN+AIN);	Not in analysis; 5.12 (2.7-10.9) h/patient day	Not stated	19 hospitals, 80 randomly selected wards, 10,132,246 discharges	UTI Decubitus ulcer Pneumonia DVT/pulm embolus GI bleeding CNS complications Sepsis Chock/cardiac arrest Pulmonary failure Metabolic derangement
Dunton 2004 USA	Cross-sectional	National database Nursing Quality Indicators. Type of hospitals not clearly stated. Units: Med-surg: 602 Med: 439 Surg: 317 Critical care: 600 Step-down: 393	RN/(RN+LPN+UAP); (median, range) Med-surg: 61% (30-100%) Med: 63% (29-100%); Surg: 64% (31-97%); Step-down: 70% (35-100%)	NHPPD median, range) Med-surg:	Not stated	282 hospitals 2351 wards	Fall rate

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

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Dunton 2007 USA	Cross-sectional	National database Nursing Quality Indicators. Type of hospitals not clearly stated.	No details provided	Not stated	Not stated	1610 units: critical care, step-down, medical, surgical, med-surgical, Rehabilitation units	Falls Hospital acquired pressure ulcers
Estabrooks 2005 Canada	Cross-sectional	Acute care hospitals (gen+ICU units)	66% (range 29-77%) RN/(RN+LPN+NA+nursing students)	Not stated	Not stated	49 hospitals, 18,142 patients (medical discharges, selected diagnoses)	30 day mortality
Everhart 2014 USA	Longitudinal/time series	Acute care geretral hospitals participating in National database Nursing Quality Indicators. 55% teaching hospitals 94% metropolitan 28% Magnet	66% %RNs/total nursing hours	TNHPPD: 8.3 h/PPD	Not stated	1,529 hospitals, number of patients not stated	Fall rates
Glance 2012 USA	Cross-sectional	US AHA survey database. Trauma patients. 47% teaching hospitals 75% non-profit	RN/(RN+LPN): Reverese function in regression model! 97% (95-98%)	HPPD 6.3 h/PPD	Not stated	70142 patients	Mortality Health care associated infections Failure to rescue

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Goode 2012 USA	Cross-sectional	Magnet- and non-Magnet Hospitals, general and ICU	Magnet: General units: 58+/-7% ICU: 75+/-6% RN hours/total hours unit staffing, aggregated at hospital level	THPPD: Magnet: General units: 11.0+7-1.6 ICU: 21.1+7-3.0 Non-Magnet: General units: 21.1+7-3.0	Not stated	19 Magnet Hospitals and 35 non-Magnet Hospitals	Mortality due to heart failure or myocardial infarction, failure to rescue, hospital acquired pressure ulcers, infections, postoperative sepsis, length of stay
He 2012 USA	Longitudinal/time line	National database Nursing Quality Indicators. 2004-2009. Type of hospitals not clearly stated	RN/total; (mean±SD): Med-surg: 63+/-11% Step-down:72+/-11%; ICU: 90+/-7% ≈Rehab: 54+/-11% %RN hours/total hours	In analysis; (h/patient day) ≈8 (Med-Surg); ≈10 (Step-down); ≈17 (CC); ≈8 (rehab)		1171 hospitals	Falls
He 2013 USA	Cross-sectional	VA hospitals (ICU, medical, surgical, mixed, step-down, spinal cord). >18 years	Non-ICU: 57+/-11% ICU: 91+/-9% % nursing hours supplied by RNs	Non-ICU: 9.42 h/patient day ICU: 15.98 h/patient day	Not stated (grouped on basis of >50% or less)	128 hospitals, 446 units, 284,097 patients Non-ICU: 236447 ICU: 47650	30 day mortality

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He 2016 USA	Longitudinal/time series	National database Nursing Quality Indicators. 2004-2012. Teaching: 695 Magnet: 119 Beds>300: 438	Falls: 70+/-20% Pressure ulcers: 76+/-4% % RN working hours	THPPD 7.6+/-4.3	Not stated	Falls: 1,622 hospitals; 13339 units; Pressure ulcers: 1527 hospitals, 12435 units	Falls Pressure ulcers
Hickey 2010 USA	Cross-sectional	Children treated for congenital heart failure	Medical: 55% Surgical: 70% ICU: 98% (range 80-100%) RN/(RN+clinical assistants+non-RN);	Not in analysis; 25.8 h/patient day (RN only)	Not stated	38 hospitals, 19,736 patients (congenital heart surgery)	Mortality
Ibe 2008 Japan	Cross-sectional (+SR)	Not clear	%RNs 89+/-9% (56-100%) RNs/(RNs+associate nurses, care workers)	HPPD: 3.03+/-1.0(1.5-8.6)	Not stated	Convenience sample: 42 hospitals	Pressure ulcer Physical restraints
Kouatly 2018 Lebanon	Cross-sectional	Acute hospital Libanon	Medicine: 55%; Critical care: 70% RN/(RN+EN);	Not in analysis; (h/patient day) Med-surg: 4.25 ICU: 15.7	81.4%	1 hospital, 68,000 patients 48 months	Falls Pressure ulcers VAP UTI
Lee 2005 Taiwan	Pre/post	Teaching hospital Taiwan	No data available	No data available	Not stated	25 nurses, 34 patients in one GI ward	Fall rate Medication error rate Patient education rate Staff satisfaction

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

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McCloskey 2005 New Zealand	Longitudinal/time line	National database 1993-2000.. Medicine and surgery.	RNs/total Skill mix increased by 18%	HPPD: increased by 7%	Not stated	65221 nurse records (85% RNs) 3290191 discharges	Mortality CNS complications Decubitus DVTs PE Pneumonia Sepsis Shock or cardiac arrest Upper GI bleeding UTI Pulmonary failure Metabolic derangement Surgical wound infections LOS
Needleman 2002 USA	Cross-sectional	Hospital discharges from 11 states. 1997+1998. Medicine+surgery Teaching and non-teaching	68 +-10%	9.0+/-2.0 %RNs/(RNs+ other)	None	799 hospitals Med: 5,075,969 Surg: 1,104,659	In-hospital death Failure to rescue UTI Pressure ulcers Hospital-acquired pneumonia Shock or cardiac arrest Upper GI bleeding Hospital-acquired sepsis DVT CNS complications Wound infection Pulmonary failure Metabolic derangement Length of stay (days)

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Needleman 2013 USA	Validation of coding design + cross-sectional	California hospital discharge datasets 200-2002. Adults only Surgical discharges, Failure-to-rescue-cases only (secondary diagnosis defining a failure-to-rescue case) Major teaching Other teaching Nonteaching	92+/-6% RN proportion of licensed hours: RN/(RN+LPN);	10.2+/- 2.6 RN hours/patient day	Not stated	480-501 hospitals , 188,731 patients	Mortality
Patrician 2017 USA	Secondary, longitudinal, and correlational analysis	Military nursing outcome database. 2003-2006.	No absolute data given, just association yes/no Skill mix som proportion av RN, LPN aller AN i realtion till totalen.	No absolute data given, just association yes/no Nursing hour/PPD	Not stated	13 military hospitals, 1,643 patients 1,104 surgery 227 step-down 222 ICU 13590 RN shifts	Hospital-acquired pressure injury (HAPI)

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Person 2004 USA	Cross-sectional + quartile-based analysis	"Almost all acute care hospitals in US, AMI cases only. 1994-1995 data. Major teaching hospitals Minor teaching hospitals Non-teaching hospitals	14.6+/-30.6 RN/LPN ratio	Not stated	Not stated	118,940 out of 234,754 patients 4401 out of 6668 hospitals	30 day mortality after AMI Reperfusion therapy Aspirin ACE inhibitors Beta-blockers
Roche 2012 Australia	Cross-sectional	Subset of previously published data from Australian public hospital system Medical/surgical/general wards 2 hospitals analysed	Not stated RN hours in proportion to total nursing hours	Not stated Rappoerterad som ett Estimate så ingen reell siffra	Not stated	2 hospitals) 14 wards (medical and surgical)	Nurse sensitive outcomes. Central nervous system complications (CNS) Decubitus Failure to rescue (FTR; death following sepsis, pneumonia, GI bleeding, or shock) Ulcer/gastro-intestinal bleeding (GI bleed) Pneumonia Sepsis Urinary tract infection (UTI)

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Sales 2008 USA	Retrospective cross-sectional	Veteran Hospitals US with acute inpatient services from VHA administrative sources. Febr-June 2003 Non-ICU + ICU	Med/surg general: 58+/-14% Gen(acute) med: 62+/-12% Surgery: 62+/-12% Med/surg ICU: 96+/-7% Med ICU: 97+/-6% Surg ICU: 97+/-5% (RN/(RNs+LPNs+NAs))	Med/surg general: 4.0+/-1.5 Gen(acute) med: 4.4+/-1.6 Surgery: 4.6+/-1.3 Med/surg ICU: 16.9/4.1 Med ICU: 15.9+/-3.7 Surg ICU: 16.7+/-4.4 (HPPD)	Independent variable hospitals with or without >50% BNs	123 VHA hospitals, 453 nursing units (282 non-ICU, 171 ICU) 129,579 patients	Mortality GI bleeding Sepsis Shock Pneumonia DVT
Sasichay-Akkadechanunt 2003 Thailand	Cross-sectional	Seven medical and seven surgical units at university hospital	45% (medical units) 48%, (surgical units) RN/total;	In analysis; 1/3-4 patients	Considered in analysis but absolute values not stated	1 hospital, 2,531 patients	In-hospital mortality

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Seago 2006 USA	Cross-sectional	3 acute care units in large metropolitan teaching hospital. 199-2002.	75% unit A 96% unit B 72% unit C	Unit A: 6.0+/-0.22 Unit B: 8.0+/-0.24 Unit C: 5.4+/-0.32 RNHPPD	Not stated	3 acute care units 103,330 patients	Satisfaction with pain management (painsat) Satisfaction with instruction (instrsat) Satisfaction with response to requests (reqsat) Failure-to-rescue (injuries) from med errors (failresm) Failure-to-rescue (serious ulcers) from decubitus ulcers (failresu)
Talsma 2014 USA	Cross-sectional	6 hospitals, General + ICU	General: 67+/-8%; ICU: 92+/-6% RN/total;	General: 7.95 h/patient day ICU: 15.07 h/patient day HPPD	Not stated	6 hospitals, 61 general care units 15 ICUs 19,313 patients	FTR: death associated with a listed number of complications
Titler 2011 USA	Cross-sectional	1 tertiary care hospital Patients aged 60 or older	64+7-14% (fall group) 71+7-10% (no fall group) RN/other caregivers; (mean±SD)	Not stated	Not stated	1 hospital, 7,851 patients	Falls

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Tourangeau 2002 Canada	Cross-sectional	75 acute care hospitals in Ontario, Canada 1998-1999 Teaching: 10 Urban community: 25 Non-urban community: 40 Adults only. Selected diagnoses: AMI, stroke, pneumonia, septicemia	75+/-11% RN/(RN+RPN+UAP);	39.9+/-7.5 Nurse staffing dose = worked hours/"Ontario case weight" (hospital level)	Not stated	75 hospitals, 46,941 patients	30 day risk adjusted mortality

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Tourangeau 2007 Canada	Cross-sectional	75 acute care hospitals in Ontario, Canada. 2002-2003. Teaching: 10 Urban community: 25 Non-urban community: 40 Adults only. Selected diagnoses: AMI, stroke, pneumonia, septicemia	Teaching hospital: 94% Community hospital: 69% All hospitals: 75% % RNs	36.2 h/weighted patient unit Nurse staffing dose = worked hours/"Ontario case weight" (hospital level)	Not stated	75 hospitals, 46,993patients AMI:19,475 Stroke: 11,160 Pneumonia: 13,433 Septicemia: 2925	30 day mortality

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Twigg 2012 Australia	Cross sectional, + time series	3 adult tertiary hospitals in Perth 2002-2004 72-80% emergency adm 20-28% elective	76-90% Hospital 1:89% (88-90%) Hospital 2: 82% (79-84%) Hospital 3: 84% (80-89) % total nurse hours provided by RNs	Not stated	Not stated	3 hospitals 52 wards 103.330 pat 73.770 nurses	(1) central nervous system (CNS) complications; (2) wound infections; (3) pulmonary failure; (4) UTI; (5) **pressure ulcer**; (6) pneumonia; (7) deep vein thrombosis; (8) ulcer/gastritis/upper gastrointestinal bleed; (9) sepsis; (10) physiological/metabolic derangement; (11) shock/cardiac arrest; (12) **mortality**; (13) failure to rescue; (14) length of stay.

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Twigg 2016 Australia	Cross-sectional Quasi-experimental pretest-posttest control group design: effects of adding AINs (assistants in nursing). 2006-2007 vs 2009-2010	3 adult tertiary hospitals in Perth Medical, surgical or rehabilitation. Wards categorized into assistant-in-nursing dominated wards (AIN wards) and non-AIN wards. 33 AIN wards 31 non-AIN wards	AIN wards: from 71% to 75% Non-AIN wards: from 82% to 85%. RN/(RN+EN);	Data stated in categories: 5.0; hours 5.75 hours; 6.0 hours; 7.5 hours Distribution; AIN wards: 24%;24%;45;;6 % Non-AIN: 16%;16;48%;19 % NHPPD	Not stated	11 hospitals, 130,540 patients 256,302 patient 125,762 pre-test period (2006–2007) 130,540 post-test period (2009–2010).	failure to rescue (death in patients with complications), **30-day mortality** (death in hospital within 30 days of admission), **falls with injury**, hospital-acquired urinary tract infection (UTI), **pressure injury**, pneumonia sepsis

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Yang 2012 Taiwan	Cross-sectional Comparison of two staff models	Medical center southern Taiwan, Respiratory care, serious pulmonary disease. Most patients on ventilator. 20 beds. 2006-2008 2 nursing staff models: Nurse and aide (247 patients) versus Nurse only (240 patients)	Nurse-and-aid: 60-70% Nurse only: 100% %RN/(RN+NA);	Not stated	Not stated	1 hospital, 487 patients (respiratory care)	**Pressure ulcer** Urinary tract infections Blood stream infections Respiratory tract infections Days of hospitalization, **Mortality** Nursing costs.

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 2 – Characteristics of included studies

Author Year Country	**Study Design**	**Setting (type of hospital, - university hospital y/n - ICU y/n Type of patients - Children/adult)**	**Skill mix (definition)**	**Nurse density (definition)**	**Nurse experience level (Proportion of BN)**	**Participants (Hospitals, Ward/nursing unit, Patients Nurses)**	**Outcome variables**
Yang 2015 Taiwan	Cross-sectional	Medical center southern Taiwan, Respiratory care, serious pulmonary disease. Most patients on ventilator. 20 beds. 2006-2010 Comparison of three nursing staff models: 76% RNs, 92% RNs and 100% RNs	3 groups: 76%, 92% and 100% %RNs/(RNs+nurse aids) .	Not stated	76% RNs: 47+/-1% BNs 92% RNs: 86+/-4% BNs 100% RNs: 55+/-9% BNs	667 pat 76% RNs: 213 92% RNs: 245 10% RNs: 209	**pressure ulcers**; urinary tract infection respiratory tract infection bloodstream infection medication errors; unplanned endotracheal tube extubation; ventilator weaning **mortality**, length of ventilator use; hospital stay

BN: Bachelor nurses, RN: registered nurses

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 3

Excluded articles

Author, year	Reason for exclusion
Abu Dagga, 2016	Wrong C/I
Aiken, 2002a	Wrong C/I
Aiken, 2002b	Wrong C/I
Aiken, 2003	Wrong I
Aiken, 2008	Wrong I
Aiken, 2011	Wrong I
Aiken, 2012	Wrong C/I
Aiken, 2013	Descriptive report
Aiken, 2014	Wrong I
Aiken, 2018	Wrong C/I
Alonso-Echanove, 2003	Wrong C
Anthony, 2008	Wrong O
Aydin, 2015	Wrong C/I
Ball, 2014	Wrong C/I
Ball, 2016	Wrong C/I
Ball, 2017	Wrong I
Barkell, 2002	Wrong O
Blegen, 2008	Wrong O
Blackman, 2018	Wrong C/I
Bolton (egentligen Burnes Bolton), 2001	Preliminary data
Bolton, 2003	Wrong O
Bowers, 2012	Wrong C
Boyle, 2015	Wrong C/I
Boyle, 2016	Wrong O
Boyle, 2017	Wrong C
Brown, 2013	Wrong O
Brown, 2010	Wrong C
Butler, 2011	Wrong C/I
Castner, 2015	Wrong O
Chamberlain, 2017	Wrong C/I

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 3

Excluded articles

Author, year	Reason for exclusion
Chang, 2011	Wrong O
Cho, 2008	Wrong C/I
Cho, 2017	Wrong O
Cox, 2001	Wrong O
Dabney, 2015	Wrong O
Dahlke, 2015	Wrong O
Dawson, 2014	Wrong O
Daykin, 2000	Wrong O
Dancer, 2006	Wrong C
Duffield, 2009	Wrong I
Duffield, 2018	Wrong C/I
Elkassabany, 2016	Wrong C
Erlingmark, 2016	Wrong C/I
Esparza, 2012	Wrong O
Friese, 2008	Wrong I
Frith, 2010	Wrong O
Frith, 2012	Wrong C/I
Garon, 2009	Wrong O
Goryakin, 2011	Wrong O
Griffiths, 2013	Wrong C/I
Griffiths, 2016	Wrong C/I
Griffiths, 2018	No skill mix data
Hart, 2011	Wrong C/I
Havaei, 2016	Wrong C/I
Hegney, 2018	Wrong O
Huang, 2011	Wrong O
Hurst, 2005	Wrong C/I
Huston, 2001	Wrong O
Jiang, 2016	Wrong C
Johannessen, 2015	Wrong C/I

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 3

Excluded articles

Author, year	Reason for exclusion
Johansen, 2011	Wrong O
Kalisch, 2011a	No skill mix data
Kalisch, 2011b	Wrong O
Kalisch, 2014	Wrong O
Kelly, 2014	Wrong I
Kerr, 2010	Wrong O
Kim, 2016a	Wrong O
Kim, 2016b	Wrong O
Kim, 2016c	Wrong O
Kim, 2018	Wrong P
Kirwan, 2013	Wrong C
Kovner, 2002	Wrong C/I
Lake, 2010	Wrong C/I
Landon, 2006	Wrong C/I
Li, 2011	Wrong O
Lu, 2015	Wrong C/I
Lundgren, 2005	Wrong O
Ma, 2015	Wrong I
Manojlovich, 2011	No results for C/I
Martsolf, 2014	Wrong O
Martsolf, 2016	Wrong O
Mattila 2010	Wrong O
McGillis Hall, 2003	Wrong I
McGillis Hall, 2003	Wrong C/I
McGillis Hall, 2004	Wrong I
McHugh, 2013	Wrong I
Mefford, 2011	Wrong O
Needleman, 2006	Reuse of data from Needleman 2002
O'Brian-Pallas, 2010a	Wrong O
O'Brian-Pallas, 2010b	Wrong O

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 3

Excluded articles

Author, year	Reason for exclusion
Oppel, 2017	Wrong O
Palese, 2015	Wrong O
Palese, 2016	Wrong O
Palese, 2017	Wrong O
Persolja, 2018	Wrong O
Pitkaaho, 2015	Wrong O
Pitkaaho, 2016	Wrong O
Recio-Saucedo, 2015	Wrong C/I
Ringerman, 2000	Wrong publication type
Sales, 2005	Wrong C/I
Schluter, 2011	Wrong I and O
Shindul-Rothschild, 2017	Wrong C/I
Smith, 2009	Wrong P
Sochalski, 2008	Wrong C/I
Spetz, 2008	Wrong C/I
Spetz, 2013	Wrong C/I
Staggs, 2012	Wrong O
Staggs, 2014	Wrong C/I
Staggs, 2017	Wrong O
Stratton, 2008	Wrong O
Sujijantararat, 2005	Wrong O
Sving, 2014	Wrong O
Tervo-Heikkinen, 2008	Wrong O
Tschannen, 2009	Wrong O
Tsiachristas, 2015	Wrong C
Twigg, 2011	No skill mix results reported
Twigg, 2013	Wrong C
Twigg, 2015	Wrong O
Unruh, 2003	Wrong I
Unruh, 2007	Wrong C/I

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and patient mortality or risk for falls or pressure ulcers?

Appendix 3

Excluded articles

Author, year	Reason for exclusion
West, 2014	Wrong C/I
Yang, 2003	Unclear skillmix definition
Yu, 2015	Wrong C/I

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.1 Mortality, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Aiken 2017 Belgium England Finland Ireland Spain Switzerland	Cross-sectional	188 hospitals, 275,519 patients (surgical discharges)	In analysis; 6.09/25 patients	RN/all; mean: 0.656 IQR: 0.564-0.741	aOR: 0.89 (0.80 to 0.98) OR: 0.90 (0.81 to 1.00) (per 10% increase) Population mortality rate: 1.28%	+	?	+
Ambrosi 2017 Italien	Cross-sectional	12 hospitals, 1,464 patients	Not clear; 207.9-211.6 min/day	RN/(RN+NA); Inhospital survivals: 0.634* (0.692-0.639) In-hospital deaths: 0.603 (0.581-0.620) (the type of reported figures not described) *point estimate not within reported CI	aOR: 0.94 (0.912 to 0.969) (% increase NR) Population mortality rate: 6.8%	+	-	+
Blegen 2011 USA	Cross-sectional	54 hospitals, ≈1,100,000 patients	Not in analysis; 11.13 h/patient day (Gen) 20.80 h/patient day (ICU)	RN/(RN+LPN+NA); mean: 0.6011 (Gen; SD: 0.0706) mean: 0.7636 (ICU; SD: 0.0565)	FTR; O/E: -0.008 (-0.01 to -0.004) (Gen); -0.009 (-0.01 to 0.03) (ICU) CHF mortality; O/E: 0.003 (-0.01 to 0.02) (Gen); -0.007 (-0.037 to 0.01) (ICU) (% increase NR) Population mortality rate NR	-	-	+

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.1 Mortality, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Blegen 2013 USA	Cross-sectional	21 hospitals, patients NR	Not clear; 11.63 h/patient day (Gen) 21.56 h/patient day (ICU)	RN/(RN+LPN+NA); mean: 0.6261 (Gen; range: 0.5170-0.7949) mean: 0.7665 (ICU; range: 0.6509-0.9300)	FTR; O/E: -0.002 (NS; Gen); -0.002 (NS; ICU) CHF mortality; O/E: 0.012 (NS; Gen); 0.005 (NS; ICU) (% increase NR) Population mortality rate NR	-	-	+
Estabrooks 2005 Canada	Cross-sectional	49 hospitals, 18,142 patients (medical discharges, selected diagnoses)	Not in analysis; NR	RN/(RN+LPN+NA+nursing students); mean: 0.66 range: 0.29-0.77	aOR: 0.76 (0.66 to 0.87) (% increase NR) Population mortality rate: 8.2%	-	-	+
Glance 2012 USA	Cross-sectional	77 hospitals, 70,142 trauma patients	In analysis; 7.9 h/patient day	LPN/(LPN+RN); median: 0.969 IQR: 0.950-0.984	aOR (with inverted definition of skillmix): 1.04 (1.02 to 1.06) FTR 1.04 (0.98 to 1.10) (per 1% increase?) Population mortality rate: 3.12%	+	-	+

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

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? Some problems
- Major problems

Appendix 4.1.1 Mortality, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Goode 2011 USA	Cross-sectional	54 hospitals, patients NR	In analysis; 11.04 h/patient day (Gen) 21.08 h/patient day (ICU)	RN/(RN+LPN+NA); mean: 0.58/0.61 (Gen; SD: 0.0725/0.0674) mean: 0.75/0.77 (ICU; SD: 0.0609/0.0535)	FTR; O/E: -0.010 (P<0.05; Gen); -0.010 (P<0.05; ICU) CHF mortality; O/E: 0.001 (NS; Gen); 0.014 (P<0.05; ICU) AMI mortality; O/E: 0.001 (NS; Gen); -0.001 (NS; ICU) (% increase NR) Population mortality rate NR	-	-	-
He 2013 USA	Cross-sectional	128 hospitals, 446 units, 284,097 patients	Not clear; 9.42 h/patient day (non-ICU) 15.98 h/patient day (ICU)	RN/total; mean: 0.57 (Non-ICU; SD: 0.11) mean: 0.91 (ICU; SD: 0.09)	aOR: 0.96 (0.93 to 1.00) (Non-ICU); 0.98 (0.90 to 1.06) (ICU) (per 10% increase) Population mortality rate: 3.77% (Non-ICU); 6.30% (ICU)	+	+	+
Hickey 2010 USA	Cross-sectional	38 hospitals, 19,736 patients (congenital heart surgery)	Not in analysis; 25.8 h/patient day (RN only)	RN/(RN+clinical assistants+non-RN); median: 0.98 (ICU; range: 0.80-1.00)	aOR: 1.02 (0.88 to 1.18) (per 5% increase) Population mortality rate: 3.56%	-	-	+
McCloskey 2005 New Zealand	Longitudinal	≈85 hospitals, ≈3,300,000 patients	Not in analysis; NR	RN/(RN+EN); 0.74 (1993); 0.93 (2000) (the type of reported figure not described, SD or range NR)	R^2 for skillmix: 0.03 (Med); p<0.05 0.50 (Surg), ns (% increase NR) Population mortality rate NR	?	-	+

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

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? Some problems
- Major problems

Appendix 4.1.1 Mortality, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Needleman 2002 USA	Cross-sectional	799 hospitals, 6,180,628 patients	In analysis; 11.4 h/patient day	RN/(RN+LPN); mean: 0.68 SD: 0.10	aIRR: 0.90 (0.74 to 1.09) (Med); 0.99 (0.67 to 1.47) (Surg) FTR: 0.81 (0.66 to 1.00) (Med) 0.73 (0.49 to 1.09) (Surg) (% increase NR) Population mortality rate: 3.2% (Med); 1.6% (Surg); NR (FTR)	+	+	+
Needleman 2013 USA	Validation	480-501 hospitals, 188,731 patients	In analysis; 10.189 h/patient day (licensed only)	RN/(RN+LPN); mean: 0.924 SD: 0.061	FTR; aOR: 0.494 (SE: 0.104, P=0.001) (% increase NR) Population mortality rate 7.60%	-	-	+
Person 2004 USA	Cross-sectional, quartile-based	118,940 out of 234,754 patients 4401 out of 6668 hospitals	Not stated	Not stated, staffing ratios in quartiles RN/LPN ratio	OR for skill mix set at one, and then compared to other independent variables. "Nursing skill mix was found not to have an independent association with mortality"	+	-	+
Roche 2012 Australien	Cross-sectional	2 hospitals, patients NR	In analysis; NR	RN/total; NR	FTR; 27% reduction (per 10% increase) Population mortality rate: 0.23% (FTR)	-	-	?

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.1 Mortality, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Sales 2008 USA	Cross-sectional	123 hospitals, 129,579 patients	In analysis; 5.1-9.3 h/patient day (Gen) 16.5-17.5 h/patient day (ICU)	RN/(RN+LPN+NA); mean: 0.53-0.70 (Gen; range: 0.36-1.00) mean: 0.96-0.97 (ICU; range: 0.62-1.00)	aOR: 0.50 (0.22 to 1.14) hospital level 1.00 (0.99 to 1.01) unit level 1.00 (0.99 to 1.01) unit level, no ICU stay 1.02 (1.00 to 1.04) unit level, ICU stay (% increase NR) Population mortality rate: 1.6% (no ICU stay); 6.7% (ICU stay)	+	+	+
Sasichay-Akkadechanunt 2003 Thailand	Cross-sectional	1 hospital, 2,531 patients	In analysis; 1/3-4 patients	RN/total; mean: 0.45-0.48 SD or range NR	aOR: 0.859 (0.580 to 1.272) (% increase NR) Population mortality rate NR	?	+	-
Talsma 2014 USA	Cross-sectional	6 hospitals, 19,313 patients	In analysis; 7.95 h/patient day (Gen) 15.07 h/patient day (ICU)	RN/total; mean: 0.6665 (Gen; SD: 0.0794) mean: 0.9151 (ICU; SD: 0.0582)	FTR; aOR: 1.000 (0.985 to 1.016) (Gen); 1.037 (0.976 to 1.101) (ICU) (% increase NR) Population mortality rate: 9.7% (FTR)	-	?	?

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.1 Mortality, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Tourangeau 2002 Canada	Cross-sectional	75 hospitals, 46,941 patients (medical discharges, selected diagnoses)	Not in analysis; 39.93 h/weighted patient	RN/(RN+RPN+UAP); mean: 0.75 SD: 0.11	Regression coefficient: -0.0489/1000 discharges (P=0.04) Corresponding to OR=0.95 (per 10% increase) Population mortality rate:1.5%	?	-	?
Tourangeau 2007 Canada	Cross-sectional	75 hospitals, 46,993 patients (medical discharges, selected diagnoses)	In analysis; 36.2 h/weighted patient	RN/(RN+RPN+UAP); mean: 0.663 SD: 0.135	Regression coefficient: -0.06% (P=0.049) Corresponding to OR=0.94 (per 10% increase) Population mortality rate: 16.9%	?	+	+
Twigg 2012 Australien	Longitudinal	3 hospitals, 103,330 patients	Not in analysis; NR	RN/total; mean: 0.885 (hospital 1); 0.815 (hospital 2); 0.841 (hospital 3) range: 0.785-0.898	Rate ratio: 0.92 (0.82 to 1.03) (hospital 1); 0.97 (0.92 to 1.03 (hospital 2); 0.98 (0.96 to 1.00) (hospital 3) FTR; rate ratio: 0.91 (0.73 to 1.13) (hospital 1); 0.88 (0.79 to 0.99 (hospital 2); 0.99 (0.96 to 1.04) (hospital 3) (per 1% increase) Population mortality rate NR	+	-	+

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.1 Mortality, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Twigg 2016 Australien	Cross-sectional	11 hospitals, 130,540 patients	Not in analysis; 5.0-7.5 h/patient day	RN/(RN+EN); median≈0.58-0.88 range≈0.40-1.00	aOR: 0.99 (0.98 to 1.01) FTR; OR: 0.99 (0.96 to 1.01) (per 10% increase in time spent on wards with low skill mix) Population mortality rate (per bed day): 0.33% (total); 0.13% (FTR)	-	-	-
Yang 2012 Taiwan	Cross-sectional	1 hospital, 487 patients (respiratory care)	Not in analysis; NR	RN/(RN+NA); 0.60-0.70 vs 1.00	20.24% (skillmix: 0.60-0.70) vs 18.75% (skillmix: 1.00) (P=0.68) Population mortality rate NR	-	-	-
Yang 2015 Taiwan	Cross-sectional	1 hospital, 667 patients (respiratory care)	Not in analysis; NR	RN/(RN+NA); 0.76 vs 1.00 vs 0.92	19.25% (skillmix: 0.76) vs 17.70% (skillmix 1.00) vs 15.10 (skillmix: 0.92) (P=0.49) Population mortality rate NR	-	-	-

aOR = adjusted odds ratio; CHF = congestive heart failure; EN = enrolled nurse; FTR = failure to rescue; Gen: general ward; h = hour; ICU = intensive care unit; IRR=Incidence rate ratio, IQR = interquartile range; LPN = licensed practical nurse; Med = medical ward; NA = nurse assistant; NR = not reported; NS = not significant; OR = odds ratio; RN = registered nurse; RPN = registered practical nurse; SD = standard deviation; Surg = surgical ward; UAP = Unlicensed assistive personnel; ? = not clearly stated in article

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.2 Falls, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Aiken 2017 Belgium England Finland Ireland Spain Switzerland	Cross-sectional	188 hospitals, 275,519 patients (surgical discharges)	In analysis; 6.09/25 patients	RN/all; mean: 0.656 IQR: 0.564-0.741	aOR: 0.80 (0.71 to 0.91); OR: 0.89 (0.79 to 1.00) (per 10% increase)	+	?	+
Ausserhofer 2013 Schweiz	Cross-sectional	35 hospitals, 997 patients	In analysis; 7.88 patients/RN	non-RN/nurses; mean: 0.3631 range: 0.1357-0.5889	aOR: 1.011 (0.988 to 1.035); OR: 1.037 (1.011 to 1.064) (per 1% increase?)	+	?	?
Bae 2014 USA	Cross-sectional	3 hospitals, patients NR	Not in analysis; 10.06 h/patient day	RN/(RN+LPN+UAP); mean: 0.795 range NR	aOR: 0.820 (SE: 0.118) (per 1% increase?)	?	-	-
Burnes Bolton 2007 USA	Longitudinal	108 hospitals, >500,000 patient days	Not in analysis; (h/patient day) Med-Surg: 8.08 (2002); 8.71 (2004); 9.07 (2006). Step-down: 9.60 (2002); 10.15 (2004); 10.47 (2006)	RN/(RN+LPN+other); (mean±SD) Med-Surg: 0.5918±0.1194 (2002); 0.6678±0.1101 (2004); 0.7034±0.1111 (2006); Step-down: 0.6951±0.1584 (2002); 0.7245±0.1375 (2004); 0.7426±0.1245 (2006)	Coefficient: -0.029, P=0.008 (per 1% increase)	+	-	+

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.2 Falls, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Cho 2003 USA	Cross-sectional	232 hospitals, 124,204 patients	Not in analysis; 8.9 h/patient day	RN/all; mean: 0.71 range NR	aOR: 0.96 (0.21 to 4.49) (per increase unclear)	+	-	-
Choi 2013 USA	Cross-sectional	576 hospitals, patients NR	In analysis; 9.04 h/patient day	RN/(RN+LPN+UAP); (mean±SD) 0.6835±0.1028	IRR: 0.997 (0.995 to 0.999) (per 1% increase)	+	+	+
Donaldsson 2005 USA	Pre/post	68 hospitals (Med-Surg); 48 hospitals (Step-down); patients NR	NA; (h/patient day) Med-Surg: 8.08 (pre); 8.68 (post) Step down: 9.59 (pre); 10.11 (post)	RN/(RN+LVN+other+contracted); (mean±SD) Med-Surg: 0.592±0.1213 (pre); 0.6667±0.1146 (post) Step-down: 0.6879±0.1533 (pre); 0.7219±0.1337 (post)	Falls/1000 patient days: (mean±SD) Med.Surg: 3.06±1.95 (pre) vs 3.19±1.74 (post) Step-down: 3.01±2.22 (pre) vs 2.62±1.56 (post) (per increase N/A)	-	-	-
Dunton 2004 USA	Cross-sectional	282 hospitals, patients NR	Not in analysis; (h/patient day) 7.5 (Med); 7.7 (Surg); 9.1 (Step-down);	RN/(RN+LPN+UAP); (mean (range)) 0.630 (0.293-0.998; Med); 0.642 (0.309-0.973; Surg); 0.697 (0.346-1.00; Step-down)	Coefficient: -0.0059 (P<0.05; Med); -0.0017 (NS; Surg) -0.0088 (Step-down; P<0.01) (per 1% increase?)	+	-	-
Dunton 2007 USA	Cross-sectional	hospitals NR, patients NR	In analysis; NR	RN/total; NR	Rate decrease: 0.7% (per 1% increase)	-	-	-

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.2 Falls, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Everhart 2014 USA	Longitudinal	1,529 hospitals, patients NR	Unclear; (h/patient day) 8.01 (high fall rate); 8.36 (medium fall rate); 8.39 (low fall rate)	RN/(RN+LPN+NA); (mean) 0.6491 (high fall rate); 0.6600 (medium fall rate); 0.6545 (low fall rate)	OR: 0.99 (0.98 to 1.01) (per 1% increase)	+	?	+
He 2012 USA	Longitudinal	1,171 hospitals, patients NR	In analysis; (h/patient day) ≈8 (Med-Surg); ≈10 (Step-down); ≈17 (CC); ≈8 (rehab)	RN/total; (mean±SD) ≈0.63±0.11 (Med-Surg); ≈0.72±0.11 (Step-down); ≈0.90±0.074 (CC); ≈0.54±0.11 (rehab) Range not clearly reported	IRR: 0.99 (0.98 to 1.00; P<0.001) (per 2% increase)	+	+	+
He 2016 USA	Longitudinal	1,622 hospitals; patients NR	Not in analysis; 10.3 h/patient day	RN/total; mean±SD: 0.7±0.2	Coefficient: -0.05 (-0.07 to -0.032) (per 1% increase)	+	?	?
Kouatly 2018 Lebanon	Cross-sectional	1 hospital, 68,000 patients	Not in analysis; (h/patient day) 4.25 (Med-Surg); 15.7 (CC)	RN/(RN+LPN+UAP); (mean) 0.546 (Med-Surg); 0.703 (CC) Range NR	OR: 2.40 (1.32 to 4.41; Med-Surg) 1.42 (0.67-2.98; CC) "less skill mix resulting in more [falls]" (per 1% increase?)	-	-	-
Lee 2005 Taiwan	Pre/post	1 hospital, 100 patients	Not in analysis; pre: n=25; post: n=29	RN/(RN+NA); pre: 1.00; post: 0 76	0 vs 0 events (per increase N/A)	-	-	-

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.2 Falls, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Titler 2011 USA	Cross-sectional	1 hospital, 7,851 patients	Not in analysis; NR	RN/other caregivers; (mean±SD) 0.64±0.14 (fall group); 0.71±0.1 (no fall group)	aOR: 0.812 (P=0.0009) (per 10% increase)	-	-	-
Twigg 2016 Australien	Cross-sectional	11 hospitals, 130,540 patients	Not in analysis; 5.0-7.5 h/patient day	RN/(RN+EN); median≈0.58-0.88 range≈0.40-1.00	aOR: 1.05 (1.03 to 1.07) (for each 10% increase in time spent om low skill mix wards)	-	-	-

aOR = adjusted odds ratio; CC = critical care; EN = enrolled nurse; Gen: general ward; h = hour; IQR = interquartile range; IRR = incidence rate ratio; LPN = licensed practical nurse; LVN = licensed vocational nurse; Med = medical ward; N/A = not applicable; NA = nurse assistant; NR = not reported; NS = not significant; OR = odds ratio; RN = registered nurse; SD = standard deviation; Surg = surgical ward; UAP = Unlicensed assistive personnel; ? = not clearly stated in article

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.3 Pressure ulcer, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Aiken 2017 Belgium England Finland Ireland Spain Switzerland	Cross-sectional	188 hospitals, 275,519 patients (surgical discharges)	In analysis; 6.09/25 pat	RN/all; mean: 0.656 IQR: 0.564-0.741	aOR: 0.85 (0.73 to 0.98) OR: 0.82 (0.74 to 0.91) (per 10% increase)	+	?	+
Ausserhofer 2013 Schweiz	Cross-sectional	35 hospitals, 997 patients	In analysis; 7.88 patients/RN	non-RN/nurses; mean: 0.3631 range: 0.1357-0.5889	aOR: 0.994 (0.962 to 1.026); OR: 0.982 (0.952 to 1.014) (per 1% increase?)	+	?	?
Bae 2014 USA	Cross-sectional	3 hospitals, patients NR	Not in analysis; 10.06 h/patient day	RN/(RN+LPN+UAP); mean: 0.795 range NR	aOR: 1.003 (SE: 0.047) (per 1% increase?)	?	-	-
Blegen 2011 USA	Cross-sectional	54 hospitals, ≈1,100,000 patients	Not in analysis; (h/patient day) 11.13 (Gen) 20.80 (ICU)	RN/(RN+LPN+NA); (mean±SD) 0.6011±0.0706 (Gen) 0.7636±0.0565 (ICU)	O/E: -0.005 (-0.02 to 0.01) (Gen); -0.011 (-0.03 to 0.01) (ICU) (per 1% increase?)	-	-	+
Blegen 2013 USA	Cross-sectional	21 hospitals, patients NR	Not clear; (h/patient day) 11.63 (Gen) 21.56 (ICU)	RN/(RN+LPN+NA); (mean (range)) 0.6261 (0.5170-0.7949; Gen) 0.7665 (0.6509-0.9300; ICU)	O/E: -0.007 (NS; Gen); -0,018 (NS, ICU) (per 1% increase?)	-	-	+

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.3 Pressure ulcer, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Boonpracom 2018 Thailand	Cross-sectional	9 hospitals, 943 patients	Not in analysis; 11.80 patients/nurse	percentage of RN; mean: 0.682 range: 0.52-0.83	β=-0.27, P<0.001 (per 1% increase?)	-	-	-
Burnes Bolton 2007 USA	Longitudinal	108 hospitals, >500,000 patient days	Not in analysis; (h/patient day) Med-Surg: 8.08 (2002); 8.71 (2004); 9.07 (2006) Step-down: 9.60 (2002); 10.15 (2004); 10.47 (2006)	RN/(RN+LPN+other); (mean±SD) Med-Surg: 0.5918±0.1194 (2002); 0.6678±0.1101 (2004); 0.7034±0.1111 (2006); Step-down: 0.6951±0.1584 (2002); 0.7245±0.1375 (2004); 0.7426±0.1245 (2006)	Not significant (figures not reported)	+	-	+
Cho 2003 USA	Cross-sectional	232 hospitals, 124,204 patients	Not in analysis; 8.9 h/patient day	RN/all; mean: 0.71 range NR	aOR: 0.75 (0.11 to 4.98) (per increase unclear)	+	-	-
Choi 2014 USA	Cross-sectional	409 hospitals, patients NR	In analysis; 11.14 h/patient day	RN/(RN+LPN+UAP); mean: 0.7432 range NR	aOR: 0.989 (0.978 to 1.001) (per 1% increase?)	?	-	+
Donaldsson 2005 USA	Pre/post	38 hospitals (Med-Surg); 28 hospitals (Step-down); patients NR	NA; (h/patient day) Med-Surg: 8.08 (pre); 8.68 (post) Step down: 9.59 (pre); 10.11 (post)	RN/(RN+LVN+other+ contracted); (mean±SD) Med-Surg: 0.592±0.1213 (pre); 0.6667±0.1146 (post) Step-down: 0.6879±0.1533 (pre); 0.7219±0.1337 (post)	% with ulcers: Med-Surg: 14.07% (pre) vs 14.48% (post) Step-down: 13.52% (pre) vs 16.29% (post) (per increase N/A)	-	-	-

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.3 Pressure ulcer, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Duffield 2011 Australia	Longitudinal	80 hospitals, 10,132,246 discharges	Not in analysis; 5.12 h/patient day	RN/(RN+EN+AIN); mean: 0.758 range NR	No figures provided, increased skillmix reported as significantly associated with decrease in pressure ulcer (P≤0.01) (per increase unclear)	-	-	-
Dunton 2007 USA	Cross-sectional	Hospitals NR, patients NR	In analysis; NR	RN/total; NR	Rate decrease: 0.7% (per 1% increase)	-	-	-
Goode 2011 USA	Cross-sectional	54 hospitals, patients NR	In analysis; (h/patient day) 11.04 (Gen) 21.08 (ICU)	RN/(RN+LPN+NA); (mean±SD) 0.58±0.0725/0.61±0.0674 (Gen) 0.75±0.0609/0.77±0.0535 (ICU)	O/E: -0.007 (NS; Gen); -0,011 (NS, ICU)	-	-	-
He 2016 USA	Longitudinal	1,527 hospitals, patients NR	Not in analysis; 10.3 h/patient day	RN/total; mean: 0.8 SD: 0.2	coefficient: -0.6 (-0.20 to -0.16) (per 1% increase)	+	?	?
Ibe 2008 Japan	Cross-sectional	Hospitals NR, patients NR	Unclear; 3.96 h/patient day	RN/(RN+AN+CW); mean: 0.8891 range: 0.5619-1.00	standardized coefficient: -1.301 (P=0.014) (per 1% increase?)	-	-	-
Kouatly 2018 Lebanon	Cross-sectional	1 hospital, 68,000 patients	Not in analysis; (h/patient day) 4.25 (Med-Surg); 15.7 (CC)	RN/(RN+LPN+UAP); (mean) 0.546 (Med-Surg); 0.703 (CC) range NR	OR: 2.07 (1.08 to 3.97; Med-Surg) "less skill mix resulting in more [pressure ulcers]" 1.37 (0.82 to 2.66; CC) "less skill mix resulting in more [pressure ulcers]" (per 1% increase?)	-	-	-
McCloskey 2005 New Zealand	Longitudinal	≈85 hospitals, ≈3,300,000 patients	Not in analysis; NR	RN/(RN+EN); 0.74 (1993); 0.93 (2000) (the type of reported figure not described, range NR)	R^2 for skillmix: 0.73 (Med); 0.86 (Surg) (per 1% increase?)	?	-	+

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.3 Pressure ulcer, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Needleman 2002 USA	Cross-sectional	799 hospitals, 6,180,628 patients	In analysis; 11.4 h/patient day	RN/(RN+LPN); mean: 0.68 SD: 0.10	States that no association was found between skillmix and pressure ulcers; no figures provided	+	+	+
Patrician 2017 USA	Cross-sectional	13 hospitals, 1,643 patients	Not in analysis; NR	RN/(RN+LPN+NA); NR	States that no association was found between skillmix and pressure ulcers; no figures provided	-	-	-
Roche 2012 Australien	Cross-sectional	2 hospitals, patients NR	In analysis; NR	RN/total; NR	19% reduction (per 10% increase)	-	-	?
Seago 2006 USA	Longitudinal	1 hospital, patients NR	In analysis; (h/patient day) 8.1 (unit 1); 8.3 (unit 2); 7.49 (unit 3)	RN/total; (mean±SD) 0.75±0.02 (unit 1); 0.96±0.04 (unit 2); 0.72±0.02 (unit 3)	Coefficient (SE): -5.7 (2.8) (Outcome: moderate/severe ulcers divided by total number of ulcers; per increase unclear)	-	-	-
Twigg 2012 Australien	Longitudinal	3 hospitals, 103,330 patients	Not in analysis; NR	RN/total; mean: 0.885 (hospital 1); 0.815 (hospital 2); 0.841 (hospital 3) range: 0.785-0.898	aOR: 0.95 (0.72 to 1.24) (hospital 1); 1.08 (0.94 to 1.23) (hospital 2); 0.98 (0.92 to 1.03) (hospital 3) (per 1% increase)	+	-	+
Twigg 2016 Australien	Cross-sectional	11 hospitals, 130,540 patients	Not in analysis; 5.0-7.5 h/patient day	RN/(RN+EN); median≈0.58-0.88 range≈0.40-1.00	aOR: 1.06 (1.04 to 1.07) (per 10% increase in time spent on wards with low skill mix)	-	-	-
Yang 2012 Taiwan	Cross-sectional	1 hospital, 487 patients (respiratory care)	Not in analysis; NR	RN/(RN+NA); 0.60-0.70 vs 1.00	1.21% (skillmix: 0.60-0.70) vs 2.92% (skillmix: 1.00) (P<0.01)	-	-	-

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, and risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.1.3 Pressure ulcer, registered nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Yang 2015 Taiwan	Cross-sectional	1 hospital, 667 patients (respiratory care)	Not in analysis; NR	RN/(RN+NA); 0.76 vs 1.00 vs 0.92	0.94% (skillmix: 0.76) vs 3.35% (skillmix 1.00) vs 1.22 (skillmix: 0.92) (P=0.12)	-	-	-

AIN = assistants in nursing; aOR = adjusted odds ratio; CC = critical care; CW = care worker; EN = enrolled nurse; Gen: general ward; h = hour; HR = hazard ratio; IQR = interquartile range; LPN = licensed practical nurse; LVN = licensed vocational nurse; Med = medical ward; N/A = not applicable; NA = nurse assistant; NR = not reported; NS = not significant; OR = odds ratio; RN = registered nurse; SD = standard deviation; SE = standard error; Surg = surgical ward; UAP = Unlicensed assistive personnel; ? = not clearly stated in article

Project: Is there an association between the proportion of registered nurses (skill-mix) in the hospital health care team, risk for falls or pressure ulcers?

* + No or minor problems
? Some problems
- Major problems

Appendix 4.2.1 Mortality, bachelor nurse compared with other staff

Author Year Country	Study Design	Number of units	Nurse density (included as a covariate in analysis; mean/median in setting)	Skillmix (definition; skillmix reported in setting)	Results	Directness*	Study limitations*	Precision*
Cho 2015 South Korea	Cross-sectional	14 hospitals, 76,036 patients (surgical discharges)	Not in analysis; 11.4 pat/nurse	BN/nurses; mean: 0.583 SD: 0.267	aOR: 0.91 (0.83 to 0.99) OR: 0.91 (0.83 to 1.01) (per 10% increase)	-	-	+

aOR = adjusted odds ratio; BN = bachelor nurse; SD = standard deviation

Region Västra Götaland, HTA-centrum

Health Technology Assessment
Regional activity-based HTA

HTA

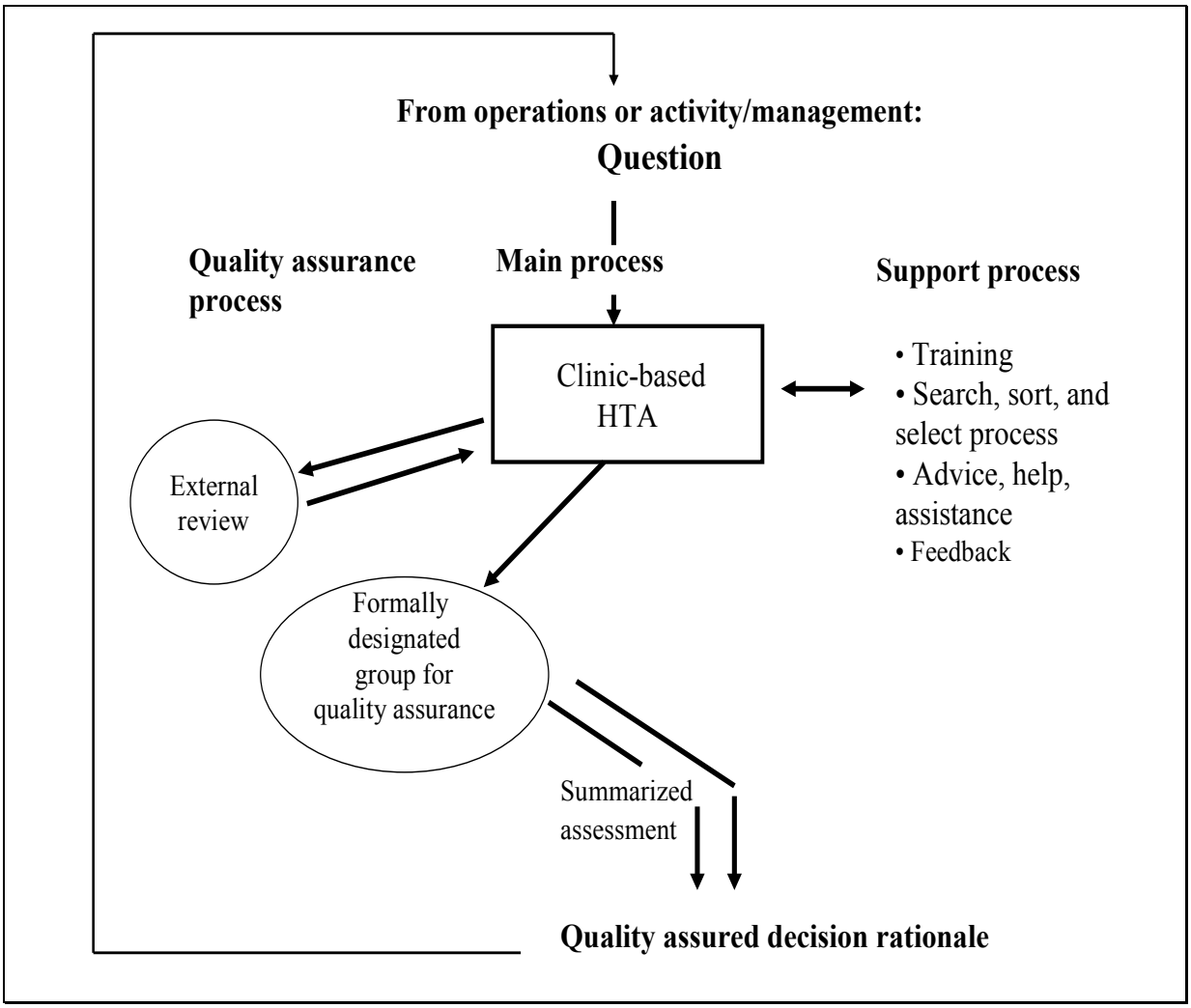
Health technology assessment (HTA) is the systematic evaluation of properties, effects, and/or impacts of health care technologies, i.e. interventions that may be used to promote health, to prevent, diagnose or treat disease or for rehabilitation or long-term care. It may address the direct, intended consequences of technologies as well as their indirect, unintended consequences. Its main purpose is to inform technology-related policymaking in health care.

To evaluate the certainty of evidence the Centre of Health Technology Assessment in Region Västra Götaland is currently using the GRADE system, which has been developed by a widely representative group of international guideline developers. According to GRADE the level of evidence is graded in four categories:

High certainty of evidence	= (GRADE⊕⊕⊕⊕)
Moderate certainty of evidence	= (GRADE ⊕⊕⊕O)
Low certainty of evidence	= (GRADE ⊕⊕OO)
Very low certainty of evidence	= (GRADE ⊕OOO)

In GRADE there is also a system to rate the strength of recommendation of a technology as either “strong” or “weak”. This is presently not used by the Centre of Health Technology Assessment in Region Västra Götaland. However, the assessments still offer some guidance to decision makers in the health care system. If the level of evidence of a positive effect of a technology is of high or moderate quality it most probably qualifies to be used in routine medical care. If the level of evidence is of low quality the use of the technology may be motivated provided there is an acceptable balance between benefits and risks, cost-effectiveness and ethical considerations. Promising technologies, but a very low quality of evidence, motivate further research but should not be used in everyday routine clinical work.

Christina Bergh
Professor, MD
Head of HTA-centrum


From operations or activity/management:
Question
Quality assurance process
Main process
Support process
Clinic-based HTA
• Training
• Search, sort, and select process
• Advice, help, assistance
• Feedback
External review
Formally designated group for quality assurance
Summarized assessment
Quality assured decision rationale

VÄSTRA GÖTALANDSREGIONEN
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