Extended-duration hospital shifts, medical errors and patient mortality

A meta-analysis was undertaken to study the association between extended medical shifts and consequences for patients. In six studies, the meta odds ratio was increased for mortality and for serious medical errors, but not for preventable medical errors and for physicians who slept >6 hours.

Night shift work is necessary within health structures to provide and maintain a high quality of care to hospitalized patients. It involves a continuous staff presence and implies the presence of a medical team, usually comprising a consultant and a resident doctor, for 24 consecutive hours on duty (or more). Overall sleep deprivation strongly impairs human functioning, and these effects have been underestimated (Pilcher and Huffcutt, 1996). Fatigue as a result of extended work duration is linked to the occurrence of medical errors, in addition to the effect it has on workers (Schernhammer et al, 2006; Fido and Ghali, 2008; Thorpy, 2011). Indeed, a reduction in shift duration reduces medical errors (Landrigan et al, 2004). Therefore, effective methods should be used to analyse the consequences of extended night work in a high-responsibility environment.

Public health policies have been implemented to reduce the number of night shifts worked by doctors, in order to limit medical errors attributed to fatigue and thus improve safety for patients. In Europe, the European Working Time Directive was introduce in 2003, in order to limit the amount of working time (e.g. every worker is entitled to a minimum daily rest period of 11 consecutive hours per 24-hour period, night workers with mental strain do not work more than 8 hours in any period of 24 hours during which they perform night work) (NHS Employers, 2011). This 'New Deal' has changed working conditions in many European countries (Tait et al, 2008; Cappuccio et al, 2009), and the effects of this directive are still debated (Cowie, 2013; Cowie et al, 2013; Morrison et al, 2013; O'Gallagher et al, 2013). In the USA, in July 2003 the Accreditation Council for Graduate Medical Education established a policy which limits the number of hours worked by interns. A reduction in the number of shifts and hours worked by interns has been shown to reduce the risk of medical errors (Barger et al, 2006). Studies of the impact of these measures were carried out in surgical fields (Jagsi et al, 2008; Rothschild et al, 2009). Although a number of reviews have been carried out, these do not include a meta-analysis (Wagstaff and Sigstad Lie, 2011; De Cordova et al, 2012; Shaefer et al, 2012).

The authors undertook a systematic review of the literature, leading to a meta-analysis of the available data regarding the association between extended-duration shifts and safety of patients.

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Methods

Literature search

Three databases (PubMed, Embase and 'Base de Données de Santé Publique' – the French Public Health Database) were used with various combinations of key words:

- 'Work Schedule Tolerance' [Mesh] AND 'Safety' [Mesh]
- ('Work Schedule Tolerance'[Mesh] AND 'Humans'[Mesh]) AND 'complications' [Subheading]
- (shift[All Fields] AND ('work'[MeSH Terms] OR 'work'[All Fields]) AND ('safety'[MeSH Terms] OR 'safety'[All Fields])) AND ('humans'[MeSH Terms] AND (Clinical Trial[ptyp] OR Meta-Analysis[ptyp] OR Randomized Controlled Trial[ptyp] OR Review[ptyp]) AND (English[lang] OR French[lang] OR German[lang]) AND 'adult'[MeSH Terms])
- 'Iatrogenic Disease'[Mesh] AND 'work schedule tolerance'[Mesh] AND ('humans'[MeSH Terms] AND (Clinical Trial[ptyp] OR Meta-Analysis[ptyp] OR Randomized Controlled Trial[ptyp] OR Review[ptyp]) AND (English[lang] OR French[lang] OR German[lang]) AND 'adult'[MeSH Terms])
- ((('Work Schedule Tolerance'[Mesh]) AND 'Safety'[Mesh]) AND 'complications' [Subheading]
- ('work schedule tolerance'[MeSH Terms] AND 'complications'[Subheading] AND (('prevention and control'[Subheading] AND ('night care'[MeSH Terms]))
- 'Work Schedule Tolerance'[All Fields] AND 'Safety'[All Fields] AND 'complications'[All Fields].

This stage of the analysis included full-text papers and reviews from the reference list drawn up from the search. The first selection of articles was performed by two independent readers based on the title and abstract. Studies with a reported association between extended work shift and consequences on patient safety were included when these consequences were clearly described or at least discussed. In the second round of the analysis, full-text papers were selected which met the same criteria, after being reviewed by the same independent readers (AD and VR).

Assessment of methodological quality

A quality assessment tool was built using criteria from the Consort 2010 checklist of information for randomized trials (Schulz et al, 2010). The list contains five topics covering 25 items: title and abstract, introduction, methods, results, discussion and other information. For the observational studies, the Strobe Statement checklist criteria were used, which include the same five topics, covering 22 items (Vandenbroucke et al, 2007). Two reviewers (VR and EL) independently assessed the quality of each study by scoring each criterion as positive or negative. The quality score for each study was calculated by adding together the number of positive criteria. The criterion used to select high-quality methodological studies was based on a total score of 15 or higher. The threshold was chosen to represent over three quarters of the scale.

Data extraction and analysis

Relevant data were extracted from the published articles. The core findings in each article were expressed using measures of association (i.e. the odds ratio) and the corresponding 95% confidence intervals. Wherever possible, such associations were directly extracted from the original article. In articles where this association was not reported, the odds ratios were recalculated for studies where sufficient raw data were available.

Results are given in terms of mortality, preventable adverse events and serious medical errors resulting from night or weekend shifts performed by interns or surgeons.

The meta-odds ratio was calculated using the generic variance approach. The weight given to each study is the inverse of the variance of the estimated effect. Heterogeneity is tested with the Q statistic. From the Q statistic, the summary odds ratio and 95% confidence interval were calculated with the random effect method. Publication bias as a result of study size was assessed by drawing funnel plots and testing with Egger's regression approach.

The meta-analysis was performed using STATA (Version 10.0; Stata Corp., College Station, TX, USA), using the PRISMA 2009 checklist (Liberati et al, 2009).

Results

During the first stage of the study, 276 papers were found in the three databases. After reading titles and abstracts and cross referencing, 30 additional papers were included. Out of these 306 articles identified as potentially relevant, 10 papers were included based on their title and abstract (*online supplement 1*). After full-text reading, three papers were excluded because they did not report mortality or medical errors (Fletcher et al, 2004; Dorrian et al, 2008; Gordon et al, 2010), and one was excluded because of lack of raw data (Chow et al, 2005) (*Figure 1*).

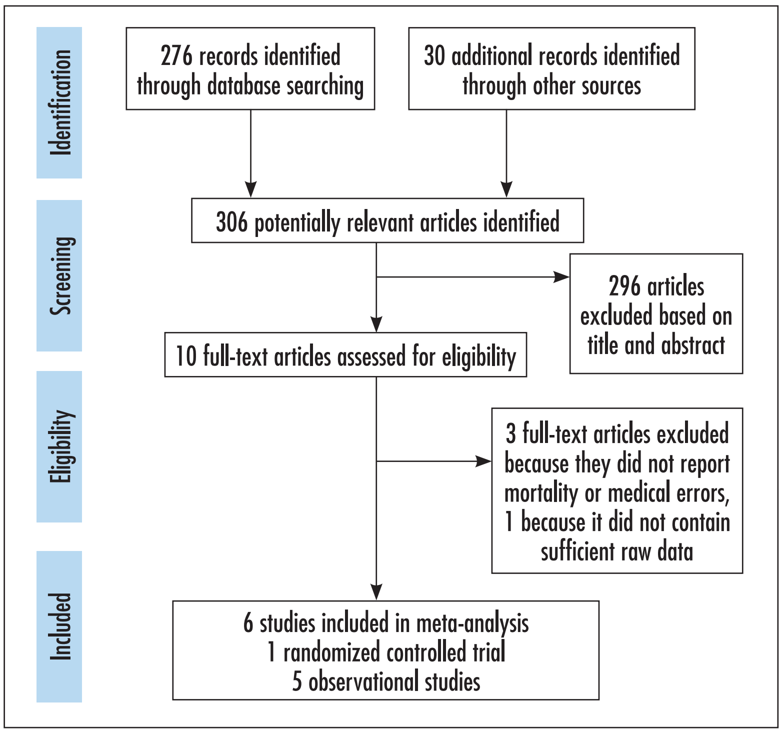
Table 1 shows the six papers selected for the meta-analysis. The studies all originated from the USA, and were published between 2004 and 2009. Among these papers, four are retrospective cohort studies (Bhavsar et al, 2007; Jagsi et al, 2008; Peberdy et al, 2008; Rothschild et al, 2009), one is a cross-sectional study (Barger et al, 2006) and one a prospective randomized study (Landrigan et al, 2004). These studies included 103 562 patients and covered a considerable period of time: up to 7–8 years for two of the studies (Peberdy et al, 2008; Rothschild et al, 2009), 2 years for one study (Bhavsar et al, 2007), and 1 year for the other three (Landrigan et al, 2004; Barger et al, 2006; Jagsi et al, 2008).

Exposure is defined by hours or shifts worked during the week by interns or surgeons. Working 24 hours or more (night or overnight) were considered, i.e. mostly >24 hours (Landrigan et al, 2004; Barger et al, 2006; Bhavsar et al, 2007; Jagsi et al, 2008), night shift (Peberdy et al, 2008), procedure during night or post-night (Rothschild et al, 2009). The reporting methods used standardized procedures involving trained personnel (Bhavsar et al, 2007; Peberdy et al, 2008), electronic screening (Rothschild et al, 2009), or direct observations (Landrigan et al, 2004).

The six selected studies meet the high methodological quality criteria (≥75%, with good agreement between the two readers >90%).

The meta-odds ratios (*Figures 2a–c*) calculated for mortality are significantly higher than 1 (*Figure 2a*), yielding a value of 1.48 (1.12–1.83). The same result is obtained for the meta-odds ratios in the case of serious medical

Figure 1. Flow chart of process of meta-analysis. Adapted from Liberati et al (2009).



errors: 1.65 (1.06–2.58) (*Figure 2c*). The meta-odds ratio for preventable medical errors is 0.994 (0.82–1.21) (*Figure 2b*).

Funnel plots do not suggest a major publication bias (*online appendix*), such as indicated by Egger's test (P>0.05).

Two studies showed a significant increase in patient mortality. This result was found for medical students working more than one shift per month, or working during night and weekend shifts (Barger et al, 2006; Peberdy et al, 2008). Serious medical errors rose significantly among interns subject to increases in numbers of shifts (Barger et al, 2006) and hours worked per month (Landrigan et al, 2004).

There was no significant increase in the rate of complications when surgeons (Rothschild et al, 2009) worked shift hours. Among physicians, the rate of complications increased when sleep opportunities were less than 6 hours. This rate was not significant when sleep hours exceeded 6 hours.

Discussion

The results of this meta-analysis support the hypothesis of an association between extended-duration shifts and an increase in mortality and medical error risks among patients. It seems that working conditions, including sleep opportunities, might explain the discrepancy observed between interns and attending surgeons. No association can be found between night shift exposure and preventable medical errors, suggesting the reasons for mortality and medical errors are complex. One study showed that reducing interns' working hours was weakly associated with the number of patients seen by each intern, even if this effect could be limited by redesigning schedules and hiring additional personnel (Jagsi et al, 2008). One study reported that not being able to sleep for at least 6 hours during the shift had an impact on the rate of complications for surgery performed after a night shift (Rothschild et al, 2009).

No study has been published on this subject outside North America. The authors assume that the results presented can be applied to the European situation because shifts are organized in a similar manner. In France, since 2003, to follow the European Working Time Directive, there is a limit on the shift duration and a mandatory compensatory rest is required after shifts (Mion and Ricouard, 2007), such as in the UK which has had an enormous impact on the human resource management of many units (Tait et al, 2008). Interestingly,

Table 1. Papers selected in the final round

Reference	Study type	Duration	Aim	No. of subjects	Study population	Times studied	Quality score	Method	Outcomes considered	Odds ratio	95% confidence interval
Bhavsar et al (2007)	Retrospective cohort study	July 2002–June 2004	Impact of duty-hours restriction by the ACGME in July 2003 on in-hospital mortality of patients with acute coronary syndromes	1003	Consecutive patients with acute coronary syndromes admitted to the University of Michigan Hospital	Pre-duty hours changes (during academic year 2002–3) and post-duty hours changes (during academic year 2003–4)	22	Data collection by trained abstractors (physicians and cardiac registered nurses) from patient records upon admission and soon after discharge or death	Mortality 24 pre-duty-hours change *vs* 12 post-duty-hours changes	1.52	(0.75–3.07)
Jagsi et al (2008)	Retrospective cohort study	May and June 2003 and May and June 2004	Impact of ACGME resident work hour limits (implemented on 1 July 2003) on in-hospital mortality of patients with acute coronary syndromes in July 2003	1498	Residents and fellows in the 76 ACGME-accredited training programs sponsored by Massachusetts General Hospital and Brigham and Women's Hospital, Boston	Pre- and post-implementation	22	Self-reporting	Preventable medical errors 44 in the 2003 group *vs* 44 in the 2004 group	1	(0.62–1.61)
									Serious medical errors 64 in the 2003 group *vs* 51 in the 2004 group	1.38	(0.89–2.14)
Peberdy et al (2008)	Retrospective cohort study	1 January 2000 to 1 February 2007	Survival to discharge from in-hospital cardiac arrest during nights	86748	Consecutive in-hospital cardiac arrest events among adults in the National Registry of Cardiopulmonary Resuscitation obtained from 507 medical/surgical participating hospitals	Day and evening hours (7:00am to 10:59pm) and night hours (11:00pm to 6:59am)	22	Specially trained quality improvement personnel (data entry personnel with formal training who must pass a certification examination before submitting any data to the central database)	Mortality 24016/28155 at night *vs* 46989/58593 during day/evening	1.43	(1.38–1.49)

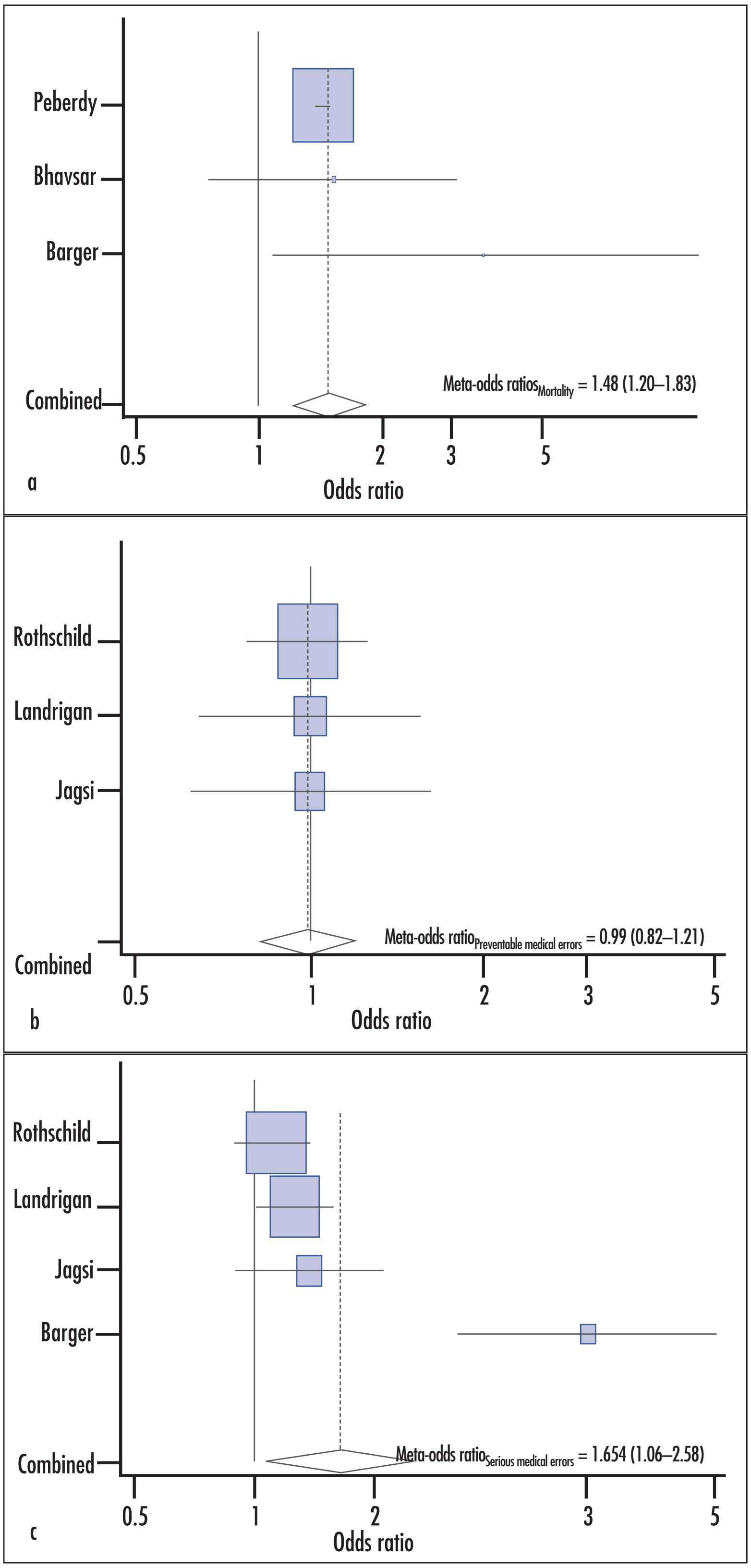
ACGME = Accreditation Council for Graduate Medical Education. *Continued overleaf*

Table 1. Papers selected in the final round (continued from previous page)

Reference	Study type	Duration	Aim	No. of subjects	Study population	Times studied	Quality score	Method	Outcomes considered	Odds ratio	95% confidence interval
Barger et al (2006)	Cross-sectional study	July 2002 to May 2003	Association between the number of extended-duration shifts worked in the month by interns and the reporting of significant medical errors and preventable adverse events	2737	Residents in their first postgraduate year (interns)	No extended-duration shift *vs* 1 to 4 extended-duration shifts during the past month	21	Monthly self-reporting	Mortality: 3 in months with no extended-duration shift *vs* 31 in months with ≥1 extended-duration shift	3.54	(1.08–11.59)
									Serious medical errors: 7 in months with no extended-duration shift *vs* 156 in months with ≥1 extended-duration shift	7.02	(3.29–14.98)
Rothschild et al (2009)	Retrospective matched cohort study	January 1999 to June 2008	Complications in post night-time procedures compared with controls	9373	Patients undergoing procedures conducted in either the operating room or labour and delivery suite between January 2000 and December 2007 in a 745-bed urban, tertiary care academic trauma centre and referral centre for high-risk obstetric procedures	Post night-time procedures (daytime procedures that followed overnight emergency procedures performed by the same attending physician at some point between midnight and 6am) *vs* control procedures (daytime procedures that did not follow overnight procedures)	22	Electronic screening for complications*	Preventable medical errors: 87 in post night-time procedures *vs* 351 in control procedures	0.99	(0.78–1.26)
									Serious medical errors: 101 in post night-time procedures *vs* 365 in control procedures	1.11	(0.89–1.39)
Landrigan et al (2004)	Randomized study	July 2002 to June 2003	Effects of reducing interns' work hours on medical errors	2203 (patients-day)	Interns of the medical intensive care unit and coronary care unit of Brigham and Women's Hospital in Boston	Intervention work schedule (elimination of extended-duration shifts and reduction of the number of scheduled hours of work to 63 per week) and traditional work schedule	22	Direct observation by physician observers for detection of serious errors in which interns were directly involved and data collection by a team of 2 nurse chart reviewers and 6 physician observers, supplemented by voluntary reports from clinical staff and a computerized event-detection monitor	Preventable medical errors: 50 with traditional schedule *vs* 35 with intervention schedule	1	(0.64–1.55)
									Serious medical errors: 250 in traditional schedule *vs* 144 in intervention schedule	1.27	(1.01–1.59)

* using ICD-9-Clinical Modification periprocedural and ob-gyn complications codes in the Agency for Healthcare Research and Quality Guide to Patient Safety Indicators and the Complication Screening Program + validated set of administrative adverse event screens including 30-day readmissions + creation of data warehouse queries using the Obstetrics Adverse Outcome Index + medical record review by two trained data abstractors

Figure 2. Forest plots based on (a) mortality as outcome, (b) preventable medical error mortality as outcome and (c) serious medical errors as outcome. The black square and horizontal line correspond to the odds ratios and 95% confidence intervals for each study. The size of the black squares reflects the weight contributed by each study to the meta-analysis. The diamond represents the meta-odds ratio with its 95% confidence interval.



this debate has recently been reopened particularly in Europe because of the effect on training, the heterogeneity of its application, and effects of the European Working Time Directive on physicians (Cowie, 2013; Cowie et al, 2013; O'Gallagher et al, 2013; Richter et al, 2013).

The methodology used to select papers and extract data may limit the validity of the meta-analysis. The authors choose to conduct a systematic and not an extensive review to focus only on high quality published study. Even though this meta-analysis is based on a small number of studies, the results appear to be homogeneous. Nevertheless, this approach might also have induced a bias. Blind reviewing with scoring could help to reduce this effect, especially considering the good agreement between the two readers.

One might also call into question the choice of data used (mortality, medical errors and preventable errors) to express the results of the meta-analysis. However, these simplifications allow the authors to gather data using similar definitions according to different criteria despite the difficulty of defining outcomes and night-shift (Knutsson, 2004; Stevens et al, 2011; Schaefer et al, 2012). Indeed, the length of a night shift might vary (8–12 hours at night), as might the times considered 'unsocial' (e.g. ending at 12 or 1 am) and these may be associated with a different medical error risk rate (Wagstaff and Sigstad Lie, 2011). The authors have only considered night or overnight shift as it was felt that these were the most relevant for patient safety. Further studies on other unsocial time frames would be of interest, such as issues related to weekend working (Peberdy et al, 2008).

The generic variance approach provides more conservative estimates (wider confidence interval) than a fixed effect model, assuming that the differences between results are solely the result of chance. A publication bias can be revealed by using the funnel plot, but Egger's test is not statistically accurate when applied to the number of trials included in this study. The authors consider that this bias is not an issue since positive and negative results are reported in the literature. They decided to focus on studies meeting high methodological criteria to be more demanding with the evidence.

A strong argument supporting the validity of this meta-analysis is the large size of the study population. In more than half of the selected examples, the studies were based on a large number of participants (interns, surgeons and patients), including a total of over 100 000 subjects and covering a long period of time (Barger et al, 2006; Peberdy et al, 2008; Rothschild et al, 2009). The reporting methods were rigorous, often involving a standardized procedure.

Fatigue resulting from sleep deprivation can be alleviated by rest (Mion and Ricouard, 2007). One study has shown that the work performance of physicians or nurses is improved in the morning following resting during a night shift (Smith-Coggins et al, 2006). Limitations of worked hours imply that organizational changes will be needed to compensate for the lack of staff and thus avoid causing more fatigue (Arora et al, 2008). More studies are required to assess the consequences on workload resulting from reductions in shift work hours, which could lead to a reduction of night sleep opportunities, and consequently an increased risk of medical errors.

Conclusions

Extended-duration shifts are weakly associated with an increased occurrence of serious medical errors and mortality among patients.

This meta-analysis has confirmed the effect of extended-duration shifts on patient safety, even though it is mitigated by some protective factors provided by the health-care system, such as limited duration of the shift, and the possibility of resting during the shift.

Further studies are necessary to explore the consequences of an increase in the workload that might result from a limitation of night shifts hours. In particular, the possibility of resting during night shifts appears to be a protective factor in terms of medical errors.

The results of these studies could be assessed in a cost-benefit analysis comparing traditional work schedules with new ways of organizing shifts which include a time dedicated to resting. BJHM

Conflict of interest: none.

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KEY POINTS

- In the context of controversy regarding the working hours and shifts of physicians, this meta-analysis confirms the effect of extended-duration shifts on patient safety.
- The meta-analysis found the meta odds ratio was increased for mortality and for serious medical errors, but not for preventable medical errors.
- However, this risk can be mitigated by some protective factors provided by the health-care system, such as limited duration of the shift, and the possibility of resting during the shift.