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REVIEW

Impact of intensive care unit light and noise exposure on critically ill patients

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Abstract

Recently, the importance of the ICU environment as a potential modifiable factor for improvement of patient care has become more clear. In this review, we describe the effects of light and noise exposure on ICU patients. In ICU patients circadian rhythms and sleep are severely disturbed, which may increase the risk of delirium. Realignment of circadian rhythmicity by means of artificial light therapy has not been shown to reduce the incidence or duration of delirium. Prudent use of nighttime light may be a first step in improvement of patient sleep. Eye masks appear to improve sleep although they are only applicable for a selected group of patients. Noise levels in the ICU are above recommended standards. Negative effects include disturbances of sleep, as often encountered in ICU patients. Staff activity and talking contribute substantially to the total acoustic energy, providing opportunities to adapt behaviour and/or workflow in order to reduce noise pollution.

General introduction

In recent years, the hospital environment has gained attention as a potentially modifiable factor that may influence patient outcome.[1] Especially in the care of the critically ill patient, the focus has always been on patient survival and the intensive care unit (ICU) environment is designed to optimally facilitate treatment. Traditionally, the beginning of intensive care originated during the large polio epidemic in the 1950s, notably in Copenhagen.[2] The necessity of mechanical ventilation of these patients led to the development of specialised wards. Over time, the possibilities for life support expanded and the amount of bedside medical equipment increased. In addition, intensive care and monitoring by specialised nurses led to round-the-clock activity in the ward. Nowadays, the detrimental effects of critical illness and ICU admission on long-term patient outcome are widely appreciated.[3] It has become clear that, in addition to patient-bound factors such as age, pre-existing conditions and severity of disease, acute illness-related factors, such as mechanical ventilation but also the ICU environment itself, may contribute to negative effects such as sleep disturbances and delirium.[4] Therefore, attention to this environment and a critical appraisal of potential modifications are justified to further improve patient care. In this review, we will focus on light and noise as modifiable environmental factors.

Physiological aspects of light exposure

Direct sunlight is of indispensable importance for life on earth. Effects of sunlight on humans can be roughly separated by their wavelengths. Ultraviolet radiation (280-400 nanometre (nm), subdivided into UV-B and UV-A) is known for its effects on the skin, most notoriously skin burns and skin cancer, but also for its immune suppressive effects.[5] Visible light (400-760 nm) is essential for vision and also the biological effects of light, while infrared light (760-1000 nm) is a form of electromagnetic radiation, associated with heat emission. The biological effects of visible light are mediated through specific photoreceptors in the retina which project onto the suprachiasmatic nucleus (SCN), which contains the principal mammalian pacemaker.[6] These photoreceptors are maximally sensitive to light with a blue colour of between 459 and 483 nm.[7] The SCN generates endogenous oscillations with a period of about 24 hours, known as circadian rhythms. The most evident example of a circadian rhythm is the sleep-wake cycle, but also body temperature, appetite and gene expression follow circadian rhythms.[6] While the pacemakers normally have endogenous rhythms, entrainment to the external light-dark cycle takes place through external triggers or 'zeitgebers' of which light exposure on the retina is the most powerful. The main output of the SCN is the rhythmical release of the neurohormone melatonin from the pineal gland. Melatonin release is normally suppressed by light exposure and under physiological circumstances melatonin levels are therefore low during the daytime.[8] Lower light levels during the evening in humans are responsible for what is known as dim light melatonin onset, leading to feelings of sleepiness.[9]

Being the main effector of the SCN, melatonin is responsible for many of the circadian effects of the SCN. Apart from its effect on timekeeping, experimental studies have demonstrated that melatonin inhibits tumour growth, affects sexual maturation and reproduction and enhances the immune response.[6] Alteration of a stable daylight schedule, such as in shift work or trans-meridian flights, may lead to well recognised disorders of circadian rhythmicity such as shift work disorder or jet lag.[10] In addition, disorders of circadian rhythmicity have been demonstrated in psychiatric diseases (depression, seasonal affective disorder) and neurological disorders, such as Alzheimer's disease.[11-13]

Of interest is the fact that daily light exposure over a longer period leads to seasonal variations in immune function.[14] Shortening of the photoperiod, which is information on a day's length, as occurs during summer and fall, may enhance melatonin secretion and improve immune function.[15]

Light exposure during and before ICU admission

Critically ill patients are surrounded by a large amount of light and noise generating equipment, obscuring natural daylight. In these rooms, intensive care is provided round the clock, often for prolonged periods of up to several months. This may lead to abnormal light exposure with daytime lighting levels often being too low and lighting levels during the night often way too high compared with normal circumstances.[16] These abnormal lighting circumstances may contribute to reduced or absent entrainment of the circadian rhythm, leading to a disturbance of this normal circadian rhythm.[17,18] Disturbances of circadian rhythm are nearly ubiquitous in critically ill patients.[19-21] Being one of the risk factors, the disturbed circadian rhythm contributes to the abnormal sleep in ICU patients. Compared with normal individuals, ICU patients experience a significant increase in arousals, an increase in sleep fragmentation and decreased percentages of REM sleep.[18] Sleep disturbances, as well as disturbances of circadian rhythm, are associated with the development of ICU-acquired delirium; however its precise relationship is unclear.[22] This cognitive disorder, occurring in up to 50% of ICU patients, is characterised by attention deficits accompanied by changes in cognition or perceptual disturbances fluctuating over time. ICU-acquired delirium is independently associated with negative long-term sequelae.[23,24]

As mentioned before, light exposure over a longer period of time may affect immune function and hence influence the outcome of ICU patients, often dealing with infectious insults. Studies in ICU patients, evaluating an association between the pre-admission light exposure and ICU mortality, have shown conflicting results.[25,26] Much is still unclear about effects of light exposure before admission on outcomes of critically ill patients, due to the multitude of factors that play a role in the outcome of ICU patients as well as difficulties in determining individual daylight exposure.

Possible solutions for disturbed light exposure

Since light exposure in the ICU is generally too low during the daytime and too high at night, the focus of interventions aimed to improve these factors should focus on these two situations.

Reducing excessive nighttime light

Critical care takes place 24 hours a day and this inevitably requires adequate amounts of artificial light, especially during the night. Prudent use of nighttime lighting as part of a multicomponent strategy to improve sleep in critically ill patients appears to be effective;[27] however, in this study nighttime lighting levels in general were low (mean <5 lux) and variations in lighting levels (e.g. switching on a general light) were considered to be more disturbing than a continuous low level light. The main issue with nighttime lighting levels in ICU rooms is that they should be low with respect to patients' needs (to be able to sleep) but sufficient light should be present to be able to provide the necessary care. A tailor-made approach for each patient, thereby determining the necessity for nighttime interventions each day instead of performing routine assessments and interventions, may provide a reasonable compromise for the contradicting interests of patients and doctors and nurses. Clustering of patient interventions and installation of quiet times indeed led to improved sleep[28,29] and are recommended in the current guidelines on pain, agitation, and delirium management.[30]

Eye masks

In recent years, studies have demonstrated beneficial effects of eye masks and, to a larger extent, earplugs on sleep and delirium in ICU patients.[31] These results have been incorporated into several national guidelines, stating that eye masks and earplugs may be offered to ICU patients to improve sleep and reduce the chance of developing delirium.[32,33] However, caution is advised in intubated patients since the application of sound and/or light masking to intubated patients may lead to sensory deprivation, especially when used together simultaneously[34] which severely reduces patient autonomy. It appears plausible that these effects specifically hold true for ICU patients, who are already prone to develop cognitive disturbances such as ICU-acquired delirium.

Improving daytime lighting in the ICU

If options are available, improving natural daylight exposure by means of creating or enlarging windows may be the first step. Additionally, other effects of a view through a window, such as feelings of wellbeing upon seeing a beautiful landscape, may play a role.[35] While earlier studies have demonstrated beneficial effects of windows on patient outcome, recent larger and better designed trials do not confirm these findings.[36,37] Installing windows as a sole way to improve outcome in critically patients therefore cannot be recommended at this time.

Artificial lighting in the ICU

As lighting levels in ICUs during the daytime are generally low, improving light by means of artificial lighting, may be beneficial. Currently, artificial lighting is being increasingly recognised as a contributor to a healing environment in healthcare settings.[38] Earlier small studies showed beneficial effects of bright light therapy on restless behaviour and delirium incidence in geriatric and postoperative patients.[39,40] However, a recent larger randomised controlled trial evaluating effects of bright light therapy in ICU patients, using ceiling mounted high-intensity fluorescent tubes, did not show a reduction in delirium incidence or duration.[41] Severity of disease, as well as mechanical ventilation and sedation, may at least partially explain these different outcomes. Of importance is the fact that many difficulties exist in evaluating effects of lighting therapy on critically ill patients. For example, the exact amount of lighting exposure on the retina in patients whose eyes are mostly closed is very difficult to determine. Additionally, effects of sedatives, known to influence circadian rhythmicity,[42] are also of importance, but nearly impossible to measure.

More research is needed into effects of light exposure on other parameters than delirium, such as the inflammatory response. In animal studies beneficial effects of lighting therapy on bacterial clearance and organ injury in experimental sepsis and ischaemia-reperfusion models have been demonstrated.[43,44] As part of this last study, a human feasibility study was also described whereby appendectomy patients were randomised between exposure to blue light for 24 hours post-surgery or having no intervention. In the intervention group, lower levels of pro-inflammatory cytokines were demonstrated,[44] suggesting that exposure to blue light dampens the inflammatory response post-surgery. A study further evaluating these findings is underway (NCT 03482245). Based on current evidence, lighting therapy cannot be recommended to reduce incidence or duration of ICU-acquired delirium. Much is still unknown with regard to other effects on patients.

Noise in the ICU

Noise is defined as any unwanted or undesirable sound which can be disruptive to normal hearing.[45] The definition of a sound being classified as noise is obviously subjective and determined by many factors, such as the nature of the sound, individual perception, cultural and social factors, the possibility of controlling the source of the noise and appropriateness to the situation. Normally, sound is defined by the amplitude (sound pressure, expressed in the unit of decibels, dB) and frequency, expressed in Hertz of a sound wave. Noise levels are normally expressed in A-weighted decibels (dBA) to account for the difference in sound perception of different frequencies of the human ear.[46] Optimal hearing takes place between 1000 and 5000 Hz and the pain threshold with respect to the sound pressure lies around 120 dB.

With respect to hospitals, the World Health Organisation (WHO) recommends that average background noise levels should not exceed 30 dBA and that peaks during the night should be below 40 dBA.[46] Unfortunately, research on sound pressure levels in hospitals in general, and ICUs specifically, demonstrates rising sound pressure levels over the years of averages up to 60-65 dBA in ICUs. This is the equivalent to a busy office, whereby the limit set by the WHO is always exceeded, especially during night-time.[47,48] Noise peaks in the ICU, up to 85 dBA, which is the equivalent of a road drill, occur as often as 16 times an hour.[48] Many factors contribute to noise pollution in the ICU. Especially noise from alarms and mechanical ventilation is typical for ICU environments, but also noise from high-intensity staff activity and discussion at the bedside play an important role.[47]

Impact of noise on ICU patients

According to the WHO, excessive noise seriously harms human health and interferes with people's daily activities at school, at work, at home and during leisure time.[46] It may disturb sleep, cause cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behaviour.[49] In the ICU, patients as well as caregivers rate noise as one of the three most bothersome experiences in the ICU.[50,51] Alarm sounds, staff conversation and noises coming from daily activities appear to be most disruptive to sleep (*figure 1*).[50,52] However, studies evaluating noise in the ICU show conflicting results as to whether noise is a significant contributor to sleep disturbances or not.[53-55] Sleep is traditionally measured using polysomnography. Polysomnography is a multi-parametric recording using neurophysiological tests such as electroencephalography, electro-oculography and electro-myography to detect biophysiological changes that occur during sleep and classify them according to validated sleep stage scoring systems. In a small group of critically ill patients (n=22), polysomnography showed that noise accounted for as little as 11.5% of arousals from sleep in mechanically ventilated patients.[54] Most studies found much higher rates of arousals caused by environmental noise.[53,56,57] Apart from the fact that different methods have been used to determine sleep quality, an important problem in assessing the value of these studies is that in many ICU patients, the electroencephalography patterns found are difficult or even impossible to classify using classical sleep staging scores. Therefore conventional scoring rules may not apply to ICU patients.[18] In addition to the direct effects of noise on sleep, unexpected noises from sources beyond the control of the patient, such as alarms, may also increase sympathetic function and negatively influence cardiac function.[58]

Reducing noise in the ICU

As already mentioned, noise sources appear to belong to three groups: 1) staff conversation and activity, 2) noise from medical devices, and 3) noise from alarms.

Adaptation of staff conversation and activity

Obviously, communication by means of talking and patient care activities are indispensable in critical care. However, a study evaluating noise sources by means of an audio recording found that a significant amount of staff conversation does not concern patient care and therefore appears to be avoidable *(figure 1)*.[47] Adaptation of behaviour seems to be a sensible approach to reduce the burden of noise pollution in the ICU. Several studies have investigated effects of nocturnal noise reduction bundles, including clustering of patient care activities, closing of doors and alarm modification and implementation of quiet times and thereby found not only improvement in sleep but also reduction in the incidence of delirium.[59,60] In addition, sleep improvement by means of a multimodal approach, including noise-reduction strategies, appears to improve patient outcomes as well.[61] However, studies in this field are hampered by methodological issues.[62] Visual warning systems that indicate excessive noise levels and thus provide feedback to caregivers are commercially available and may reduce average sound pressure levels;[63] however, evidence of its effectiveness in decreasing noise in the ICU is limited.

Earplugs

Earplugs as a means of reducing the burden of excessive noise and to improve sleep are cheap interventions used at home or during travelling. Their use in ICU patients, either alone or in combination with eye masks, to improve sleep and reduce delirium has been investigated in several studies. A recent review, including 19 studies involving 1379 participants, concluded that earplugs showed positive effects on sleep quality and delirium incidence.[64] These results should be interpreted with caution due to selection bias and because of the use of different methods of measuring sleep quality.[64,65] Obviously, earplugs can only be used in a selected subgroup of patients, due to the previously mentioned risk of sensory deprivation. When the patient is awake and cooperative, however, the use of earplugs may provide a cheap and effective method to decrease the burden of environmental noise.

Alarm modification

Alarms contribute significantly to noise pollution in the ICU. Apart from the mere acoustical energy, also the unfamiliarity as well as its unpredictability play a role in the perception of alarms as being disturbing.[66] Many of the alarms being generated are false alarms and only a minority lead to interventions.[67] Studies have shown that alarm modification appears feasible and leads to significantly less alarms. For example, delaying an alarm for several seconds leads to a significant reduction in false alarms.[68] Also, adaptation of alarm limits and daily replacement of electrodes appears to lead to a significant reduction in the number of alarms.[69]

Conclusion

In this review we have described the physiology and impact of light and noise on critically ill patients. While the negative influence of the ICU environment on critically ill patients has become clear in recent years, much is still unknown on the effects of light and noise on the individual patient. A multimodal approach, including improvement of daily light exposure and reduction of excessive noise to improve sleep and reduce unnecessary stimuli appears to be a reasonable and easy step to improve the care of the critically ill patient. Objective and measurable outcome criteria, such as incidence and duration of delirium and sleep quality, as well as patient-reported outcome measures, should be able to provide an adequate insight into the effects of these interventions. In this respect, the results of a prospective observational study on the influence of a multimodal adaptation of an ICU environment, including light and noise exposure, on patient outcomes are eagerly awaited (clinicaltrials.gov no. NCT02143661). Future research should demonstrate whether specific forms of light therapy, structural adaptations and/or behavioural modification may further improve patient outcomes.

Disclosures

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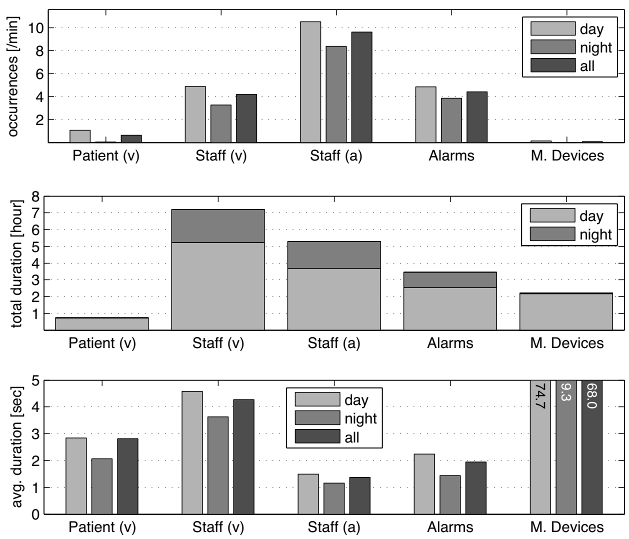

Figure 1. Average number (occurrences of sound events/min), accumulated duration and average duration of events during a 24-hour annotation of an ICU audio recording, according to their source. Patient (v) = conversation from the patient; Staff (v) = staff conversation; Staff (a) = staff activities; M. Devices = medical devices. Reproduced from Park et al., Journal of the Acoustical Sciences of America 2014 135(4) 1875-86, with the permission of the Acoustical Society of America

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