Noise in Health Care

WHITE PAPER

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Introduction

> Unnecessary noise is the most cruel absence of care which can be inflicted either on sick or well.
>
> *Florence Nightingale*
> *1859*

In the 19th century Florence Nightingale wrote the above quote and was one of the first to bring a focus on noise in health care. At the time a revolutionary development in technology had begun. Today, this development has resulted in high tech societies across the world. A new range of possibilities and treatments exist but the new technological solutions also bring consequences such as new origins of sound. Some sound is pleasant to the surroundings but often the opposite is the case. According to the World Health Organization (WHO) the unpleasant sound - noise - has a negative effect on the health of the population.In the publication 'Burden of disease from environmental noise' from 2011 the results indicate *that at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe* [1].On the large scale this indicates a problem of noise in general through the loss of healthy lives.This raises the question about the unhealthy lives. Numerous ill patients are treated at hospitals everyday. Hospitals that ideally offer quiet and peaceful surroundings for the patients to recover in. However, several studies elucidate that noise is an extensive problem in hospitals [2, 3, 4, 5, 6]. In 2005 Busch-Vishniac et al. presented a study from Johns Hopkins Hospital which found that the average sound pressure levels had risen from 57 dB(A)[1] in 1960 to 72 dB(A) in 2005 [7]. WHO is aware of the issue and states the following guidelines for hospitals: *For wardrooms in hospitals, the guideline values indoors are 30 dB* L_{Aeq}[2]*, together with 40 dB* L_{Amax}[3] *during the night. During day and evening the guideline value indoors is 30 dB* L_{Aeq} [8]. Still, reports show that hospitals struggle to decrease noise and to comply with the guidelines [3, 9, 11].

First and foremost, this white paper will give the reader an idea of the problems that patients and hospitals face due to the exposure to noise. A better insight in the complex problem is given by reviewing what the sources of noise are. This will be followed by a description of the effects of noise on patients' physiological conditions. The field of noise in hospitals is big and much literature deal with the issue. Not all of this literature is included in this white paper.

[1] dB(A): A-weighted sound pressure level (SPL) reduces the effect of low frequencies in order to imitate the human sound perception.

[2] L_{Aeq}: A-weighted equivalent sound pressure level in decibel.

[3] L_{Amax}: A-weighted maximum sound level.

Origins of Noise

To reduce sound levels in hospitals it is essential to know where the noise is coming from. Different studies try to cover this field and the results show that there is a vast number of noise sources [10, 11, 12, 13, 14, 15].
Noise measurement is not a trivial science. Noise can be measured in simple sound pressure level, in several types of weighted decibel (A, B, C) or in perceived loudness etc. Noise is also subjective and often dB-levels do not describe an annoyance of noise adequately. Noise is also relative to background sound levels. Stanchina et al. [16] found that the effect of noise on sleep depended on how much the noise level varied from the background sound level.
The scientific literature on noise in health care is most often conducted by health care professionals who are highly skilled in medicine but lack a full understanding of acoustics, noise and how to measure it. This leads to moderately incomparable results in the scientific literature, and the literature sometimes lack information on how the measurements were conducted. Even though measurement methods vary, the scientific literature still gives a good idea of the different noise sources at hospitals.

There has been a common belief that alarms from medical equipment were the dominant contributor to noise which Tegnestedt et al. support in a 2013-study from Karolinska University Hospital, Stockholm [10]. In the study, disruptive sound sources were observed in three different patient rooms. In all of the rooms alarm equipment was the main source of noise when looking at number of occurrences per hour. The study also indicates that a big part of the disturbing sounds were *conversation unrelated to patient care.*
Other studies conclude that additional noise sources also have a great influence on the sound environment. In 2014 Park et al. [11] published a study which annotated a 24-h recording in an intensive care unit (ICU) in the Netherlands. Results show that noise sources are many. It extends from plastic ripping and paper noise to staff talking and non-verbal sound from patients. Opposite to the study from Stockholm, this study indicates that alarms are not the most dominant noise source. The study concludes that the most dominant sources were patient-involved speech, patient's non-verbal sound and staff-generated noise. Furthermore, the results show that the greatest contributors to noise was either direct or partly controlled by human factors. Dube et al. published a study in 2008 [12] in which patients were asked about noise sources. It found that the most annoying source was people talking and patients felt that mornings between 7 AM and noon was the most annoying time of the day.

In a 1998-study Kahn et al. show that talk and television were the major causes of noise in a medical ICU and respiratory ICU setting [13]. The study claims that out of the noise identi-

fied, 51% were potentially modifiable. This indicates that some noise may be inevitable while some is preventable. A British study from 2007 shares this belief. MacKenzie et al. show that 34% of the noise sources found were totally avoidable while 28% were partially avoidable. To give an idea of what could be done, noise that could be avoided were falling lids on rubbish bins, chair scraping and doors closing and squeaking [14].

Noise sources vary and are therefore to be handled in different ways. Hospital units are different in equipment, furniture, organization, staff and routines which makes it impossible to create a universal solution to the complex noise problem. Therefore it is important to determine what the actual sources are in the individual unit and make modifications based on that if possible.

Physical Impact of Noise

We now have an idea of what is responsible for noise in hospitals and how complex the problem can be.The impact of noise is individual just like the sound impression is subjective. In 1976 Fife et al. [17] compared the length of hospital stay between two different groups of patients exposed to different noise environments. One group was hospitalised during construction work next door and was therefore exposed to an increased noise level. The control group was patients hospitalised in the same ophthalmology unit one year before and after the construction. Results show that *hospital stay was significantly longer during the period of construction.* This indicates that noise can have an influence on patients' course of disease and admission length. The following sections will list the known physical consequences of noise.

Sleep disturbance

A big part of the healing process takes place while sleeping [18]. This is a known factor in the hospitals and several studies investigate what negative impacts noise have on patients' sleep in different settings.

There are two main effects of how noise influences patients' sleep. Noise is first of all capable of disrupting sleep, resulting in an awakening. In 2001 Freedman et al. [19] published a study showing that 17% of the involved patients' overall awakenings were due to environmental noise. The study was executed in an ICU including 22 patients - 12 males and 10 females. An effect is also stated in a 2004 review-study by Parthasarthy et al. which showed that 11-20% of all arousals and awakenings in an ICU were due to noise [20].
Apart from awakenings, noise can also affect humans' sleep cycle in different ways. Aurell and Elmquist deals with this problem in their study from 1985 [21]. The study which was carried out in a postoperative ICU shows that all patients *had severe or complete suppression of sleep stages 3 and 4 and REM and lacked the normal inherent rhythmicity of sleep.* The fact that noise has an effect on different parameters of sleep is supported in a 2003-study. Gabor et al. [22] investigate how disruptive ICU noise stimuli effect both mechanically ventilated patients and healthy participants. They found that sound elevations *were responsible for 20.9% of total arousals and awakenings.*
Additionally, Buxton et al. [23] published a study in 2012 in which 12 healthy participants were exposed to 14 different hospital sounds for two nights in a sleep laboratory. EEG measurements and infrared video monitors were used to determine arousals and movements of the persons as a respond to the noise exposure. The study found that the effect on patients varied depending on the sound stimulus and on which stage of sleep patients were undergoing. Both N2, N3 and REM stages were influenced by the noise exposure. Buxton et al. also conclude that the effect

of noise on hospitalised patients may be underestimated because the experiment was performed on healthy persons.

Freedman et al. [19] also look at the influence of noise on sleep stages. The study shows that a part of the patients who participated did not undergo any period of REM sleep through a 24-hour period. Furthermore, nonseptic patients exposed to noise had a sleep cycle in which sleep stage 1 was predominant and all other stages were decreased in duration. Persson et al. [24] support these statements with a 2013-study which shows that noise had a negative effect on sleep, causing awakenings and a decreased time in which patients were in sleep stage 3 and REM sleep.
In 1993 Topf and Davis published a study in which 70 non-hospitalised women participated [25]. The experiment took place in a sleep laboratory and used audiotaped recordings derived from a critical care unit (CCU). Results show that the women who were exposed to noise while sleeping overnight *showed poorer REM sleep on seven of 10 measures* compared to the women who were not exposed.
Evans and French's publication from 1995 explains why a disturbance in patients' sleep cycle can have serious consequences [26]. It states that a *deprivation of REM sleep for more than 24 to 48 hours is associated with psychological disturbances such as: apathy, depression, irritability, illogical thinking, confusion, disorientation, combativeness, delusions, hallucinations and paranoia*. Furthermore the 1995-publication explains that *deprivation of NREM sleep leads to: immunosuppression, decreased tissue repair, decreased pain tolerance, and profound fatigue of the central sympathetic nerve centers*. There is a possibility that these effects can lead to further complications in patients' course of disease. If patients suffer from immonosuppression or decreased tissue repair they will be more vulnerable to other diseases and/or heal slower, which may result in longer hospitalisations.
Noise and sleep research show how sleep is an important healing factor for patients in hospitals and it illuminates how noise works as a negative stressor resulting in awakenings and changes in patients' sleep cycle.

Delirium

Delirium is a mental condition which expresses itself as disorientation in regards to consciousness and cognition. The condition is characterized by an immediate occurrence, and patients often experience fluctuating between being delirious and not [27].

Patients who experience delirium are at risk of serious health consequences. In a study from 2004 Ely et al. [28] illuminate that both the length of hospital stays and patients' mortality after six months increase significantly when delirium is present. The study was carried out in a medical and coronary ICU and enrolled 275 consecutive mechanically ventilated patients.
The question is what makes the patients experience delirium and how can the risk be reduced? Risk factors of developing delirium are found to be many and there is not one specific cause. Yet, noise is shown to be one of the sources which contribute to an increased risk of

developing delirium. Several studies investigate the direct connection between delirium and noise [29, 30, 31, 32, 33]. Pol et al. published a study in 2017 which investigates how a nocturnal sound reduction protocol impacts patients and the incidence of delirium in an ICU [29]. A pre- and post-intervention group involving 421 patients in total were compared. Results show that in the post-intervention group incidences of delirium were reduced by 12.4% ($p<0.002$). Patients in the post-intervention group experienced less noise and therefore needed less sleep-inducing medication. In the study Temazepam and Midazolam medication were used which both belong to the benzodiazepine pharmalogical class. Pol et al. describe that *Benzodiazepines are strongly associated with the transition from a non-delirious to a delirious state.* When patients' sleep medication is reduced because of a reduction in noise they are less likely to develop delirium.
More studies show a significant decrease in the development of delirium when using noise reduction interventions. Among noise reduction interventions is the use of earplugs [31, 29, 32, 34]. In a 2016-meta study Litton et al. [34] concludes that *placement of earplugs in patients admitted to the ICU[...] is associated with a significant reduction in risk of delirium.*
Some studies do not find a significant connection between noise exposure and delirium [30, 31]. One of these studies was published in 2012. Johansson et al. executed the study in a Swedish ICU an the study group comprised 13 patients. In the study no statistical connection between high sound levels and early signs of ICU delirium occurred but they stated that *more research in this area is needed.*
As described in the previous section, *Sleep disturbance*, several studies point out that noise can contribute to a lack of sleep and changed sleep cycles. Studies show that there is a link between sleep deprivation and the development of delirium [33, 34, 35]. Thereby noise can have an indirect influence on patients developing delirium.
The reason for reducing the incidences of delirium is mainly patient related. Further, hospitals can also profit from decreasing the incidences of delirium. An American study from 2008 shows that patients with delirium can cost up to 2.5 times as much as patients without delirium [36].

Several studies show a connection, both direct and indirect, between noise and delirium. However it is still important to keep in mind that several risk factors play a part in the occurrence of delirium. In 1999 Inouye et al. published a study which concludes that an intervention strategy for preventing delirium in hospitalised older medical patients should be multicomponent [33]. A reduction of noise would not exclude all incidences of delirium but it would still be a big steep in the right direction.

Cardiovascular system

In 2012 Hsu et al. [37] published a meta study which among other things describes what impact noise can have on the cardiovascular system. Among others the impact is seen on heart rate and blood pressure. Marshall's study from 1972 illuminates that the mean heart rate increased when patients in an intensive coronary care unit were exposed to human speech [38].
A 1981-study published by Conn [39] investigates the connection between noise in a CCU and

arrhythmia. 25 male patients were exposed to several one-minute noise sequences for one hour at two different times of the day. The study shows that there was an increase in ventricular arrhythmia in the periods with noise (periods defined by a noise level greater than 55 dB). Furthermore, results from a 2005-study shows that the heart rate of patients in a surgical ICU rose significantly when speech took place in patients' room [40]. In the study Hagerman et al. also claim that the patients exposed to bad acoustics have a higher incidence of re-hospitalisation.

In Baker's study from 1992 [41] 28 adult patients in an surgical intensive care unit (SICU) participated. Supporting Marshall's study [38] the result shows that patients' heart rate was increased by noise. Patients had very individual responses to noise but overall there was a trend which indicated that the heart rate rose. The study also investigates the relation between different noise sources and responses from patients. The outcome shows that 57% of the patients had the greatest increase in heart rate when the noise source was talking inside the room.

Summary

Increased sound levels in hospitals result in health risks for patients. Noise varies in sound and origin which makes it a complex problem that needs to be solved with a variety of solutions. Hospital units vary and counter-measures against noise must be based on the conditions in the individual unit. No matter the origin, noise has negative consequences for the patients. Possible consequences are sleep deprivation expressed through awakenings and changed sleep cycles, delirium, cardiovascular changes such as ventricular arrhythmia and both increased heart rates and blood pressure. Furthermore, patients are at risk of longer hospitalisation and re-admissions when exposed to noise. This white paper shows that there is a great potential in dealing with the noise problem in order to optimise the hospital environment for patients recovery which would be beneficial for both patients and hospitals.

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