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Exploring the Therapeutic Potential of Acoustic Interventions in Healing Environments

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Abstract

High noise levels in hospitals pose risks to both patients and staff, inducing stress, discomfort, and restlessness. This study presents results from a noise survey conducted in a Dhaka teaching hospital, revealing daytime levels ranging from 48 to 63 dB LAeq, exceeding Bangladesh standards. Noise levels correlated with ward layout and sources, not patient demographics. Strategies such as noise reduction, acoustic materials, and staff/patient programs can improve hospital acoustics effectively. This study reviews research from multiple disciplines including medicine, psychology, architecture, and acoustics, focusing on topics such as hospital noise, sleep quality, patient privacy, and music therapy. Findings indicate hospitals often exceed recommended noise levels, negatively impacting patients and staff with sleep problems, higher blood pressure, and burnout. Poorly designed sound environments compromise patient privacy and communication. Strategies like private rooms, sound-absorbing materials, and music therapy are recommended to reduce noise levels and improve communication. To enhance patient confidentiality, private rooms with sound-blocking features are suggested. Overall, the study underscores the importance of sound management in healthcare and advocates for design strategies to mitigate noise-related issues while ensuring effective communication.

KEY WORDS: Noise, patient, acoustic, healthcare, hospital.

1.Introduction

The impact of sound in hospitals varies greatly, from being comforting and therapeutic to causing stress and discomfort for patients, staff, and visitors. It's widely recognized that many hospitals have noise levels that far exceed recommended guidelines, as established by Busch-Vishniac et al. in 2005. This excessive noise, often referred to as "unwanted sound" in research literature, can have negative effects on the health of both patients and staff.

Another crucial aspect of sound in hospitals is speech intelligibility and audibility, which are essential for effective communication among patients and staff, as well as between staff members. However, the risk of confidential patient information being overheard by unintended listeners raises concerns about patient confidentiality, speech security, and privacy.

The various dimensions of sound, from disruptive noise to soothing music and clear speech, highlight the importance of designing environments that minimize unwanted sound transmission while maximizing speech intelligibility for effective communication.

These challenges related to sound control and transmission are interconnected, and various environmental design strategies have been

successful in mitigating the negative effects of noise while facilitating effective verbal communication.

The aim of this paper is to explore how different aspects of sound, such as noise, speech privacy, speech intelligibility, and music, impact patients and staff in healthcare settings. Additionally, it aims to examine specific environmental design strategies that can enhance the acoustical environment of healthcare facilities.

Unwanted sound or noise poses a significant threat to the well-being of both patients and staff (Joseph and Ulrich, 2007). Noise disturbances disrupt patients' rest, negatively impacting their health (Topf, 1985; Freedman et al., 1999; Parthasarathy et al., 2004). Higher noise levels can induce stress in patients, leading to an increased need for pain medication and potentially prolonging their length of stay (Fife and Rappaport, 1976; McCarthy et al., 1991). Additionally, noise levels in hospitals can influence patients' perception of the quality of care provided. In addition to causing annoyance, stress, and fatigue, elevated sound levels contribute to emotional exhaustion and burnout among hospital staff. According to Joseph and Ulrich (2007), noise within hospitals hampers clear communication among staff and can result in medical errors due to compromised speech intelligibility. The persistent rise in noise levels within hospitals and its detrimental effects on users are of grave concern. It is imperative to maintain noise levels in hospital wards within recommended standards and guidelines, as outlined in Table 1.

Table 1: Noise level standards in hospital wards

Standards	Recommended Sound Pressure Level
WHO (Berglund et al., 1995)	35 dBA at Day Time 30 dBA at Night Time
ANSI (1999)	25 – 40 dBA NCB: 25-40
International Noise Council [Cited in (Konkani and Oakley, 2012)]	45 dBA at Day Time 20 dBA at Night Time
BNBC (2015)	33- 48 dBA NCB Curve: 25-40

Limited research exists on this topic within the context of Bangladesh, prompting this study to address the gap. The primary objective was to assess noise levels in various ward layouts of a naturally ventilated government hospital. However, due to time constraints, a specific case study was chosen representing common ward layouts in current Bangladeshi hospitals. The study aimed to achieve the following objectives:

1. Identify common noise sources present in these wards.
2. Highlight factors influencing noise levels in the wards.
3. Recommend noise control solutions to mitigate noise sources and levels in hospital wards

2.METHODOLOGY

Over the past decade, architects have been adhering to a standardized design prototype for government teaching hospitals in Bangladesh. While variations exist in terms of height, orientation, and functions based on site-specific requirements, most wards share similar characteristics. For this study, a specific teaching hospital in Dhaka, following this prototype, was selected for field survey. The wards were arranged

in two or more parallel blocks oriented in a north-south direction, interconnected by corridors or waiting areas.

Among the surveyed wards, two surgery wards (Figure 1) were located on the 6th floor, while one medicine ward (Figure 2) was situated on the 8th floor. Each ward block comprised rooms with 8, 10, or 12 beds arranged in double-loaded bays.

The ward layout featured a central nurse station surrounded by long corridors on both sides. Patient accommodation was typically situated on one side, while staff rooms, kitchens, and healthcare resources were located on the other.

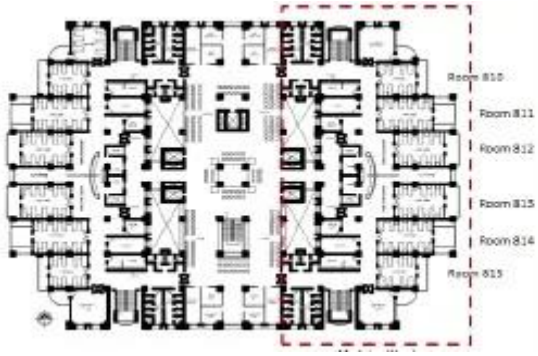

Figure 1: 6th Floor Plan (Surgery wards-1&2)

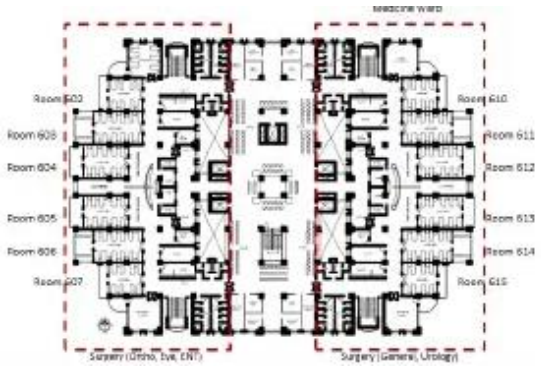

Figure 2: 8th Floor Plan (Medicine ward)

3.Noise sources

Loud noises louder than 60 dBA were noticed and documented in Table 3. Knowing about these noisy events can help us figure out how to avoid or control them. These noisy events don't follow a specific pattern and depend a lot on things like the condition of patients, the time of day, and what type of ward it is. For example, during meal times, we often hear loud noises from food trolleys and things dropping or moving in the hallway. Other studies have found similar noisy events, which confirms that these noisy sources are real. Most of the time, the constant noise comes from people talking or using phones, which can range from 60 to 80 dBA. Some other noises happen randomly without any clear pattern.

4.Factors affecting noise levels in hospital wards

Table 3: Commonly occurred noise sources and their typical levels

Type of Noise	Noise of source	Measured Noise level L_{Amax}
Ward equipment	Moving food Trolley	65+
	Moving medical supply trolley	70-76+
Ward furniture	Door closing	76+
	Metal cupboard door and drawer	50-66+
People Noise	Footsteps in the busy corridor	60-64
	Patient's coughing	70-74+
	Patients groaning or crying out	70-80
	Phone ringing	60+
	Talking on phones	66+
	People conversation in high voice	62-65+
	Conversation between nurse and caregivers	64-74
Others	Object dropping on floor	70+
	Object dropping on trolley	78+
Noise from Surrounding	Train Horns	64+
	Traffic (Horns)	69+
	Construction Site	70+

Factors contributing to high noise levels in hospital wards include the presence of loud noise sources like mechanical equipment, staff conversations, and noise from visitors or patients. Additionally, the use of sound-reflecting materials on surfaces exacerbates noise levels. Let's break down the findings:

1. **Room Size**: Noise levels were observed to be high in both large and small rooms, indicating that room size alone does not determine noise levels. Factors such as the number of caregivers and activities around patients significantly influence noise levels.

2. **Ward Type**: Despite similar layouts and routines, the noise level was higher in the medicine ward compared to surgery ward-2. This difference is attributed to factors such as patient load, density of people, types of patients, and care provided. The presence of acutely ill patients, exhibiting behaviors like crying or groaning, also contributed to higher noise levels in medicine wards.

3. **Ward Design**: Analysis revealed that noise from ancillary spaces, particularly nurse stations, significantly contributed to high noise levels in patient accommodation areas. Even though wards had identical layouts, noise levels varied due to the distribution of noise sources within the ward.

4. **Reverberation Times (RTs)**: The use of sound-reflecting materials on surfaces, such as walls, ceilings, and floors, resulted in high noise levels and long reverberation times in the wards. This phenomenon caused sounds to echo, overlap, and linger, affecting communication and speech intelligibility. While reverberation times could not be calculated due to time constraints, many staff members reported difficulties in communication due to lingering noise in the wards.

5. Noise in healthcare settings

The healthcare sector grapples with a well-documented issue: pervasive noise within hospitals worldwide. According to the World Health Organization (WHO), recommended noise levels for hospital patient rooms are 35 dB(A) during the day and 30 dB(A) at night, with nighttime peaks not to exceed 40 dB(A). However, research spanning several decades reveals a consistent failure to meet these guidelines. Instead, hospital noise levels have steadily increased since the 1960s, with daytime levels rising from 57 dB(A) to 72 dB(A) and nighttime levels from 42 dB(A) to 60 dB(A). Additionally, numerous studies highlight peak noise levels often surpassing 85 dB(A) to 90 dB(A), akin to the noise experienced near a busy highway during the passage of motorcycles or large trucks.

Safety regulations specify that the maximum safe level of noise exposure for an eight-hour shift without ear protection is 85 dB(A), as outlined by the National Institute for Occupational Safety and Health in 1998. To put the extraordinary loudness

of typical hospital sounds into perspective, consider that an 85 dB(A) noise is 100,000 times greater in sound pressure than the recommended daytime level of 35 dB(A) for patient areas. Therefore, it's understandable that elevated noise levels in hospitals can have significant consequences for the health and well-being of both staff and patients

5.1. Impacts of noise on patients

Significant research has delved into the adverse effects of noise on both patients and staff within hospital settings. Besides being a source of irritation, loud noises in hospitals have been associated with sleep disturbances and interruptions among patients. Various studies conducted among neonatal intensive care (NICU), pediatric, and adult patients have identified noise as a cause of awakenings and disruptions in sleep patterns. However, alongside noise, other factors such as patient-care routines also contribute to sleep disturbances and require attention as part of a comprehensive intervention to enhance sleep quality.

Maintaining quiet periods is particularly crucial in NICU environments, where high noise levels can lead to decreased oxygen saturation, elevated blood pressure, increased heart and respiration rates, and worsened sleep quality. There is some indication that noise negatively affects wound healing, as evidenced by studies where patients experienced longer hospital stays following surgery during periods of heightened noise due to construction activities. Additionally, research suggests that higher noise levels correlate with increased medication requirements among surgery patients during the recovery phase.

A recent study In Sweden examined the effects of modifying room acoustics in an intensive coronary care unit (CCU) on patient and staff outcomes. When sound-absorbing ceiling tiles were installed to improve acoustical conditions, patients in acute myocardial infarction and unstable angina pectoris groups exhibited lower pulse amplitudes compared to periods with poor acoustical conditions. Patients also reported higher satisfaction with the care provided by staff during improved acoustical conditions. Importantly, patients treated during periods of poor acoustical conditions had a higher incidence of hospital readmission.

5.2. Impacts of noise on staff

Noise in hospitals can cause stress for medical staff and potentially disrupt their effectiveness at work. In the Swedish study focusing on room acoustics, researchers discovered that when acoustical conditions were improved, staff encountered fewer work demands and reported reduced feelings of pressure and strain.

Limited research has focused on how noise affects the performance of healthcare staff, and the findings are mixed. Studies conducted in laboratory settings with non-healthcare groups have shown that noise often does not hinder task performance when there is motivation to exert more effort or pressure to maintain high standards. These findings suggest that individuals may compensate for noise-related challenges by increasing effort, as indicated by heightened cardiovascular responses and other physiological reactions. This suggests that healthcare professionals might be able to maintain their performance standards in noisy environments, albeit at the cost of increased effort and fatigue.

A small number of studies have investigated the work performance of anesthetists and surgeons under various sound conditions, such as quiet versus simulated noisy conditions. These studies generally found that noise did not significantly degrade performance. However, one study observed declines in short-term memory and mental efficiency among anesthetists working in typical operating room noise conditions, where noise levels exceeded 77 dB(A). Under such

conditions, the threshold for speech reception increased by 25 percent, indicating that speech communication was only possible by speaking louder, while speech discrimination decreased by 23 percent. Clearly, these conditions could increase errors among hospital staff and pose significant risks to patient safety.

6.Why are hospitals noisy?

Hospitals tend to be noisy for two primary reasons. Firstly, there are numerous sources of noise present, and secondly, the surfaces within hospital environments—such as walls, floors, and ceilings—are often designed to reflect sound rather than absorb it. Various sounds contribute to the high noise levels in hospitals, including mechanical equipment such as alarms, paging systems, telephones, and computer printers, as well as noises from ice machines, staff conversations, and activities of roommates and visitors. Many studies have identified staff conversation as a significant contributor to loud noises within hospital units.

The presence of hard, sound-reflecting surfaces exacerbates the noise issue in hospitals. These surfaces cause noise to travel considerable distances, spreading down corridors and into patient rooms, and negatively impacting both patients and staff across larger areas. Sound-reflecting surfaces commonly found in hospitals lead to echoes, overlapping sounds, and prolonged reverberation times. Reverberation refers to the persistence of sound in an enclosed space, resulting from multiple reflections after the sound source has ceased.

The reverberation time of a room refers to the duration It takes for sound to diminish by 60 dB(A) after the sound source has ceased, and is primarily influenced by the presence of sound-absorbing materials within the room. According to the Joint Subcommittee on Speech Privacy of various organizations, such as the Acoustical Society of America, Technical Committees for Architectural Acoustics and Noise, the Institute of Noise Control Engineering, and the National Council of Acoustical Consultants in 2006, the use of sound-absorbing materials helps in absorbing sound, preventing it from accumulating.

In environments where there are long reverberation times due to acoustic conditions, echoes occur, causing sounds to blend and overlap, consequently reducing speech intelligibility. To compensate for this reduced intelligibility, staff members may raise their voices, exacerbating the noise issue further.

7. Environmental strategies to reduce noise in hospitals

Research indicates that implementing environmental changes can effectively reduce noise levels in hospitals and enhance the overall acoustical environment. Key interventions include installing high-performance sound-absorbing ceiling tiles, minimizing or eliminating noise sources (such as adopting noiseless paging systems), and transitioning to single-bed rooms instead of multi-bed rooms.

Sound-absorbing ceiling tiles have been shown in several studies to decrease noise levels and perceptions of noise, while also improving outcomes such as speech intelligibility and reducing perceived work pressure among staff. Although the decibel levels were not significantly reduced in these studies (typically a reduction of 3 to 6 dB(A)), there was a notable decrease in reverberation times and sound propagation. This led to a perception of reduced noise within the unit and improved speech clarity, which has implications for effective staff communication.

Single bed rooms

Single-bed rooms are considered one of the most effective strategies for reducing noise levels in patient rooms. Studies conducted in acute-care and intensive-care units have demonstrated that most noises originate from the presence of other patients, including staff interactions, equipment noise, and patient activities such as coughing or movement. Patient satisfaction data also supports the effectiveness of single-bed rooms, with patients consistently reporting higher satisfaction levels with noise levels in and around their rooms compared to those with roommates. This finding holds true across various patient demographics and characteristics, highlighting the universal preference for single rooms in terms of noise levels.

Eliminating or reducing the noise sources

Reducing or eliminating noise sources in hospital environments is a critical step in mitigating loud noises. Various studies have pinpointed overhead paging systems, equipment, and loud staff conversations as primary contributors to noise levels on hospital units. Recommendations for noise reduction commonly include replacing overhead paging with cell phones or wireless communication devices carried by staff, removing sources of loud noises like ice machines, powering off equipment when not in use, conducting group conversations in enclosed spaces, and educating staff on the importance of speaking quietly and maintaining a tranquil environment.

Many healthcare facilities are adopting wireless communication systems, although their effectiveness in reducing noise levels remains uncertain. For instance, a shift from overhead paging to personal wireless networks in an emergency department did not lead to decreased noise levels. However, another facility successfully reduced overhead pages by over 50 percent within two years after transitioning to a wireless communication network.

Staff education initiatives and designated quiet hours have shown some success in reducing noise levels and improving patient outcomes such as sleep quality, although the sustainability of these results over the long term is unclear.

A combination of environmental interventions, such as providing private rooms, installing sound-absorbing ceiling tiles, and using soft flooring, along with education programs, is likely to be the most effective approach in reducing noise levels and enhancing acoustic conditions for both patients and staff in healthcare settings.

8. Speech privacy and patient confidentiality

In many hospitals and outpatient medical offices, patients often find themselves in situations where they overhear conversations involving other patients or have their own private information shared in open environments, which can potentially impact patient trust and their willingness to freely discuss health concerns with their physicians. This issue was highlighted by a study in an emergency department, where 5 percent of patients examined in curtained spaces reported withholding parts of their private history and refusing portions of their physical examination due to lack of privacy. Such instances can have serious implications for patient safety.

In recent years, concerns regarding patient confidentiality have gained prominence, with the Health Insurance Portability and Accountability Act (HIPAA) of 1996 emphasizing the need for reasonable safeguards to protect patient information, including orally communicated information. Therefore, ensuring that private conversations involving patients remain confidential is crucial.

Speech privacy, which refers to the extent to which a private conversation can be overheard by unintended listeners, is measured by a privacy index (PI). This index, expressed as a percentage, takes into account the acoustical properties of various finishes within a space, such as ceilings, floors, partitions, and furniture. The levels of speech privacy are categorized as confidential, normal, marginal or poor, and no privacy, depending on the PI rating.

Recommendations from the Interim Sound and Vibration Guidelines for Hospitals and Healthcare Facilities suggest that normal speech privacy should be provided between enclosed rooms, while confidential speech privacy is recommended in areas such as admitting areas, patient consultation rooms, psychiatric testing rooms, and examination rooms.

The design of the physical environment significantly influences patient confidentiality and speech privacy in healthcare settings. While limited studies have explored the role of unit design or architecture in maintaining privacy, some have compared the visual and auditory privacy of patients in multi-bed spaces with curtain partitions to those in rooms with solid walls. These studies revealed that breaches of patient confidentiality were more common in multi-bed spaces with curtain partitions, leading patients to withhold information due to a perceived lack of auditory and visual privacy.

Various challenges posed by unit design and layout contribute to difficulties in ensuring patient confidentiality, including inadequate private discussion spaces in public areas, physical proximity between staff and visitors, multi-occupancy rooms, open-plan examination areas, incomplete office walls, non-absorbing ceilings, and insufficient private discussion rooms on patient units for physician meetings with families. These factors, combined with the careless communication practices of staff, exacerbate the problem of maintaining patient confidentiality and speech privacy in healthcare settings.

Undoubtedly, architectural design interventions could effectively address some of the glaring shortcomings observed in healthcare environments concerning the preservation of patient confidentiality. One particularly endorsed design approach, backed by robust research, is the provision of single-patient rooms or enclosed rooms with walls in examination and treatment areas, where patients are required to disclose confidential health information. Patient satisfaction data from Press Ganey, as reported by Ulrich and colleagues, revealed a consistent preference for single-bed rooms among patients compared to those with roommates, particularly regarding concerns for privacy. This preference was echoed by nurses in a survey across four West Coast hospitals, with an overwhelming majority favoring single rooms for patient examination and history collection.

Another strategy sometimes recommended to enhance speech privacy is sound masking, defined as the precise application of electronic background sound to cover up unwanted noise. While proven effective in open-plan commercial offices, its applicability and impact in healthcare settings remain uncertain. Given the multifaceted auditory demands in healthcare work, including alarms and spoken communication, the potential effects of sound masking on speech intelligibility and recognition errors among staff and patients should be thoroughly researched before widespread implementation.

It's evident that the environment plays a crucial role in promoting patient privacy and confidentiality. Further studies are warranted to investigate the influence of different room layouts, finishes, and unit configurations on privacy and

confidentiality breaches in various areas of healthcare settings, including patient rooms, hallways, nursing stations, reception areas, and waiting rooms.

9. Speech intelligibility

Speech intelligibility and speech privacy are closely interconnected, with the primary aim often being to enhance communication effectiveness among relevant parties (e.g., hospital staff, staff-patient interactions) while minimizing the comprehensibility of their conversation to unintended listeners, thereby achieving speech privacy. Particularly in healthcare settings, where nurses and physicians must swiftly understand and respond to various auditory cues in a fast-paced and stressful environment, the issue of speech intelligibility holds significant importance compared to other contexts such as offices.

Moreover, the shift towards digitalized hospital operations necessitates the use of speech-recognition systems. While individuals with normal hearing can typically discern speech amidst background noise, automated speech recognition systems require a higher signal-to-noise ratio for accurate interpretation. A subpar acoustic environment may lead to errors in automated transcription of medical notes and dispensing of medications.

Although ceiling sound-masking systems are effective in enhancing speech privacy in open-plan office settings, their suitability in dynamic healthcare environments like nurses' stations remains largely unexplored. Research is imperative to ascertain whether such systems could potentially compromise speech intelligibility and increase error risks in healthcare scenarios.

As discussed earlier, the presence of hard, reflective surfaces exacerbates reverberation, which significantly impacts speech intelligibility. Studies have demonstrated that installing high-performance sound-absorbing ceiling tiles effectively reduces reverberation times. In a Swedish study, the implementation of sound-absorbing tiles led to improved speech intelligibility and higher patient satisfaction with staff attitudes compared to periods with poor acoustics.

In healthcare settings, it's essential to install sound-absorbing ceiling tiles and similar materials to decrease reverberation times and enhance speech clarity. Additionally, areas designated for private communication, like inpatient rooms, examination, and treatment rooms, should ideally have single rooms with ceiling-to-floor walls to minimize external noise interference and ensure speech confidentiality.

10. Impact of music

Music encompasses intricately arranged sounds consisting of rhythm, pitch, harmony, and melody. Studies indicate that certain types of music can induce relaxation and positive responses, leading to decreased activity in the neuroendocrine and sympathetic nervous systems, resulting in reduced anxiety, heart rate, respiratory rate, and increased temperature.

This therapeutic use of music, known as music therapy, has been applied in various medical settings, including oncology, maternity, postoperative care, intensive care, coronary care, and pediatrics.

Patient preferences play a crucial role in the effectiveness of music therapy, as individual tastes vary based on factors like age, culture, and peer group. Typically, sedative music suitable for therapeutic intervention lacks accented beats,

percussive characteristics, has a slow tempo, and features a smooth melody.

Studies have demonstrated the benefits of music for patients undergoing painful procedures. For instance, research on mechanically ventilated patients in intensive care units revealed that listening to relaxing music reduces subjective states of anxiety and emotional disturbance, as well as physiological outcomes like heart rate and respiratory rate. In a study comparing patients who listened to music through headphones with those who had a rest period with no music, physiological measures significantly improved among those who underwent the music intervention.

Similarly, women undergoing Caesarean delivery experienced lower anxiety levels and higher satisfaction when they listened to music during the procedure. Other studies have shown that music reduces anxiety in mothers caring for preterm infants in neonatal intensive care units and alleviates acute postoperative confusion and delirium in elderly patients undergoing elective hip and knee surgery.

Research indicates that personalized music tailored to individual preferences is beneficial in reducing behavioral issues and agitation among dementia patients. Similarly, studies involving children have shown that playing recorded lullabies effectively distracts them and reduces overall distress during routine immunizations, typically played at a decibel level suitable for comfort

A review by Cooke and colleagues in 2005 examined twelve experimental studies Investigating the impact of music on anxiety and other outcomes in patients waiting in ambulatory-care settings, such as day surgery facilities. Across all studies, patients who listened to music reported lower levels of anxiety, with the music typically played at comfortable decibel levels conducive to relaxation.

While there is robust evidence supporting the effectiveness of music therapy in alleviating pain and anxiety among patients, most studies focused on patients listening to music either through headphones or nearby cassette players, ensuring a comfortable listening experience. Few studies explored the impact of ambient music on patient outcomes, and none investigated its effects on staff and families. Future research should delve into these areas to further understand the broader implications of music intervention in healthcare settings.

11. CONCLUSION

Sounds affect both patients and staff in various ways. Unwanted noise is a significant issue in hospitals worldwide, with high noise levels adversely impacting the health and well-being of patients and staff, potentially delaying patient healing. Conversely, certain types of music can alleviate anxiety and distress among patients. Poorly designed environments can lead to private conversations being overheard, breaching confidentiality. Additionally, inadequate acoustics hinder effective communication by making speech less clear, posing safety risks for patients. Improving the hospital's acoustical environment through thoughtful design can mitigate noise, enhance speech clarity, and bolster patient confidentiality. Key design factors include:

- Implementing single-patient rooms, which offer lower noise levels, increased perceived privacy for patients, and facilitate more effective and confidential communication between staff and patients.
- Installing high-quality sound-absorbing acoustical ceiling tiles to reduce reverberation times, limit sound propagation, and enhance speech intelligibility. Additionally, this approach enhances speech privacy by minimizing sound transmission to adjacent areas.

- Eliminating or reducing noisy sources within hospital units and educating staff on the impact of noise on both patients and themselves, thereby lowering noise levels.
- Ensuring that patient examination rooms and treatment areas feature walls that extend fully to the support ceiling to prevent the transmission of voices and noise through ceilings.

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