BNAM 2018
Baltic-Nordic Acoustics Meeting
15-18 April 2018
Harpa, Reykjavík, Iceland

Noise and room acoustic conditions in a tertiary referral hospital in Seoul, Korea

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Noise levels and room acoustic parameters at a tertiary referral hospital, Seoul National University Hospital in Korea, are investigated. Through a questionnaire, acoustically problematic rooms are identified. Noise levels in emergency rooms (ERs) and intensive care units (ICUs) are measured over about three days. Acoustically critical and problematic rooms in the otolaryngology department are measured: examination rooms, operating rooms, nurse stations, patient rooms, and audiometric rooms. The equivalent A-weighted noise level, L_{Aeq}, ranges from 54 to 56 dBA in two ERs. In an ICU, the noise level for the first night was 66 dBA, which came down to 56 dBA for the next day. The reason for the higher noise level for the first night in the ICU was frequent alarm sound and treatment noise related to a critical patient. The noise level in the measured ERs is about 10 dB lower than those measured in other ERs in the US, which range from 65 to 73 dBA. The noise levels during three different ear surgeries vary from 57 to 62 dBA, depending on the use of surgical drills and suctions. The noise levels in a patient room is found to be 47 dBA, while the nurse stations have a high noise level up to 64 dBA, even noisier than the ERs. The reverberation time, T_{20}, in an operation room, examination room, and single patient room are found to be satisfactory below 0.6 s.

1 Introduction

Hospitals, in general, are known to be not quiet according to various studies, see for examples [1,2]. Acoustically most interesting rooms in hospitals are two-fold: rooms where patients need good quality tranquility to focus on healing and rooms where staff needs concentration. As the medical care is absolutely prioritized, hospitals would never consider acoustic and noise conditions very importantly. With help of the department of Otorhinolaryngology of SNUH, permission was given to measure several rooms in the hospital for a limited duration of four days. Among others, the most interesting, critical, and most difficult in terms of getting permission are emergency rooms (ERs) and intensive care units (ICUs). In the Otorhinolaryngology department, there are several acoustically critical rooms, namely the audiometric rooms, examination rooms, nurse stations, operating rooms, and patient rooms. This is the first attempt to measure the hospital soundscape thoroughly in a Korean tertiary referral hospital to the authors' knowledge.

2 Method

2.1 Basic checklist for measuring noise and acoustics in hospitals

The list of items that should be checked before acoustic measurements is summarized as follows:

1. Have a quick tour of the rooms to be measured accompanied by a doctor or nurse, who knows the place and work pattern well, for example, ER and ICU.
2. Find a "secure" place for a sound level meter, which does not disturb the working paths of the staff, especially where lots of equipment is moving and the medical staff is busy and hectic.
3. Attach a note "Don't remove – noise measurement on-going" with the name and telephone information.
4. Think about who will be most affected by noise, either staff or patient. E.g., patient's perception may not be important in rooms where they are mostly unconscious.
5. Now-or-never scheme: a great care should be taken not to lose the data.
6. Practice the equipment so that one can set it up very quickly.
7. Estimate the time duration and prepare both sufficient memory cards and batteries accordingly (AC power preferable).
8. Think about how long recording should be done (within the given permission). Critically think if the measurement/recording is representing well what is intended to be measured.
9. Distribute a questionnaire beforehand to figure out what to measure and to identify problems, if possible. Also having a quick discussion with the head nurses is a good way to quickly identify important problems.
10. Save data and check the equipment regularly, e.g., everyday (not to lose all data by unexpected accidents)

2.2 Questionnaire

First, a questionnaire was distributed throughout the hospital in late November 2017. Most answers were collected from the staff in the Otorhinolaryngology department. The questionnaire basically asked to rank the noise sources, and how severe the noise and acoustics-related problems (mostly about reverberation) are. It was unsure at the time of questionnaire that we could get permission to measure all the rooms we would like to. 45 answers were collected.

The noisy room rankings are shown in the left subfigure of Fig 1. The most problematic rooms in terms of room acoustics are shown in the right subfigure of Fig. 1. The mean rating regarding noise was 2.2 out of 5, 1 being "not at all disturbing" to 5 being "extremely noisy". The mean rating for bad acoustics was 2.0, which is equivalent to 'slightly disturbed'. One of the main noise sources that was mentioned in several answers was construction noise, which was severe due to an underground expansion of the hospital at the time of questionnaire. Figure 2 shows the main noise sources.

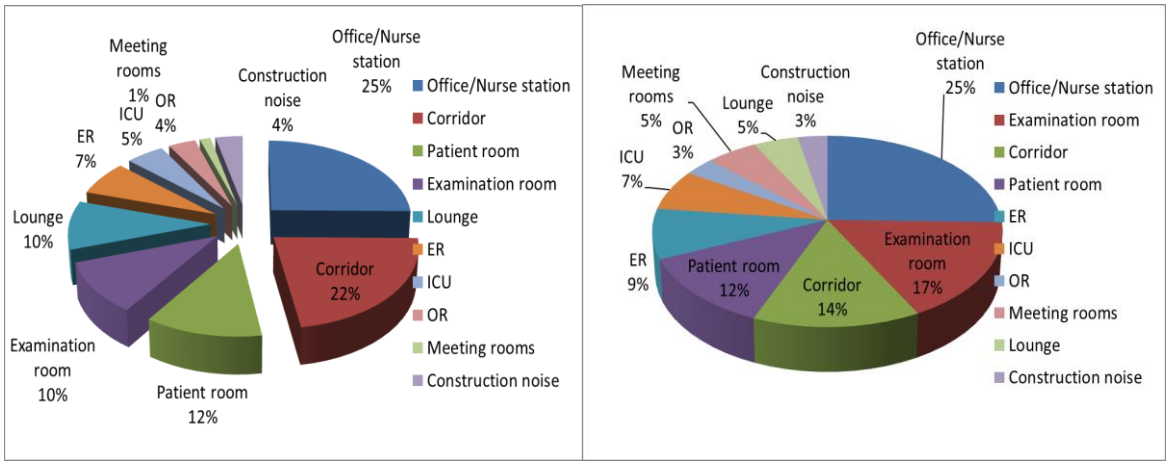

Figure 1: Left: Noisy rooms, Right: rooms with bad acoustic conditions.

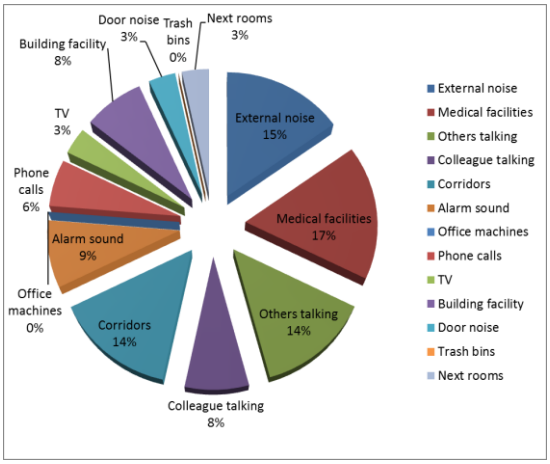

Figure 2: Main noise source ranking.

2.3 Measurement procedure

The measurement campaign was planned through several meetings with an Otorhinolaryngology doctor. The measurement was performed in late December 2017. We used three B&K 2270 and four Larson and Davis 831c machines. A Dirac system (ver. 3.0) with a B&K 4130 microphone and a B&K 4292 omni-directional source was used for room acoustic measurement according to ISO 3382-2 [3].

On the first day, we had a short tour at the hospital, and decided to measure the rooms available only that day. When we visited the ERs and ICUs, it was rather quiet and not too busy. The whole emergency department was refurbished throughout 2017, to have a triage room in the middle, being connected to several small sections with a small number of beds. A sound level meter was installed with logging function on at a safe place close to the ceiling of the triage ER so that no one could easily touch. Another SLM was securely installed near a patient bed in a treatment ER section, which happened to be close to the nurse station. This measurement location could be the loudest spot in this ER section. However, the most important consideration in determining the measurement spot was a security/safety of the sound level meter, meaning that nobody was likely to touch it or stop it by any means. In addition, it should not disturb working paths between the patients and nurses, so ideally hanging from the ceiling could be an option. However, the ceiling installation in this hospital could not allow any sound level meters to be hung from the ceiling.

The same consideration was done at a surgical ICU. At the ICU chosen, the main focus was the medical staff's disturbance, because most patients in this ICU were unconscious, so noise was unlikely to be strongly correlated to their healing.

In other rooms, we measured noise and acoustics for less than an hour at each measurement position. The reverberation time measurement sometimes could not comply with ISO 3382 precision method [3] due to the limited time permitted. For the same reason, T_{20} was chosen to be reported with some exceptions of EDTs at lower frequencies of 125 and 250 Hz.

3 Results/Collected data

3.1 ERs - Triage and treatment section

L_{Aeq} at the triage section was 55.6 dBA over the first 22 hours, 55.7 dBA over the next 21 hours, and 55.6 dBA for the rest 22 hours. The noise level in the treatment ER was measured to be 54.5 dBA, 53.9 dBA, and 52.4 dBA for the same time intervals, respectively. The noise level did not vary too much over the three days, so it could be regarded to be representing the noise level in the ER.

3.2 A surgical ICU

We measured quite different noise levels for two days. For the first 22 hours, the noise level was quite high as 65.7 dBA, with several intervals with L_{Cpeak} of 112.4 dBC. Next day a nurse answered that there was a critical patient, so the alarm rings constantly and medical team was busy. For the next 15 hours, the noise level went down to 56.2 dBA. Unfortunately, the third day noise data were not saved properly for unknown reasons.

3.3 Operating rooms – noise, RT, and background noise

Three ear surgeries were measured. An implantation surgery of cochlear prosthetic device was regarded to be relatively noisy by using surgical drills and suctions. The measurement started after changing to a smaller drill and its average L_{Aeq} was 59.3 dBA. A canal wall down mastoidectomy was measured, where drills and suctions were used, with the average noise level being 62.5 dBA. Lastly, an intact canal wall mastoidectomy was measured, which was regarded as a quite surgery. Particularly, the measurement started after drilling, so the noise level was lowest as 57.4 dBA. The same consideration for choosing the measurement spot was made: security and unobtrusiveness of the noise measurement device. The dimensions of the operation rooms were 5.8 m × 9.4 m × 3.5 m (H). The background noise was measured to be 49.2 dBA. The spatially averaged early decay time (EDT) over 5 measurement positions in this surgery room was measured to be [0.48, 0.58, 0.53, 0.56, 0.55, 0.44] s from the 125 Hz to 4 kHz octave bands.

3.4 Examination rooms – noise and RT

The examination rooms in the Otorhinolaryngology department were similar in size, shape, and equipment installed. One room was measured, of which the dimensions were 3.5 m × 4.0 m × 3.0 m (H). The sound transmission between the examination rooms was not measured but one could hear noise from the next door. The background noise including the construction and HVAC noise was not low as 49.6 dBA. The noise from medical devices varied between 55 to 65 dBA during examinations. The reverberation time T_{20} in an empty condition was measured to be [0.50, 0.43, 0.40, 0.37, 0.32, 0.29] s from the 125 Hz to 4 kHz octave bands.

3.5 Audiometric rooms – RT and background noise

There were three booths for audiometry and ABR measurements. The dimensions were 2.3 m × 2.0 m × 2.0 m (H), 1.9 m × 1.8 m × 2.0 m (H), and 1.9 m × 1.5 m × 2.0 m (H), respectively. The reverberation time was sufficiently short, all being below 0.2 s and the background noise level with the door closed was measured to be 27.5 dBA.

3.6 Nurse stations – noise

The nurse station was pointed out to be most noisy in the questionnaire. The measurement confirmed this statement: the noise level at the nurse station ranged 58-64 dBA in several measurements near wards, examination rooms, and children department, which was even noisier than ERs. More details can be found in Table 1.

3.7 Patient rooms, single vs multiple rooms – noise and RT

The noise levels in two different patients' rooms were measured. First, in a single patient room, the background noise level with all doors and windows closed was 37 dBA. With the windows open, the background noise level went up to 50 dBA due to the construction noise outside the building even in an unoccupied condition. The reverberation time T_{20} was measured to be [0.40, 0.33, 0.31, 0.33, 0.30, 0.25] s from the 125 Hz to 4 kHz octave bands. In a patient ward with 8 people in an occupied state, L_{Aeq} was 47 dBA, which was regarded relatively quiet.

4 Discussion and Conclusions

The World Health Organization (WHO) guidelines for community noise include noise limits in hospitals, suggesting that the noise level should not exceed 35 dBA L_{Aeq} for areas where patients are treated and observed [4]. This is almost impossible to achieve, e.g., the noise levels measured in an UK ICU are all higher than 54 dBA close to patients [5], and L_{Aeq} in the emergency department of Johns Hopkins hospital ranges from 65 to 73 dBA [6], which is significantly

higher than in the ERs at SNUH. The Danish Building Regulation (BR18) sets a maximum reverberation time of 0.6 s for examination rooms and patient bedrooms in the frequency range of 125-4000 Hz [7]. Although this recommendation does not apply in Korea, the reverberation time measured in the examination and patient wards in SNUH seems satisfactory.

A summary of the noise and acoustic measurements are shown in Tables 1 and 2. Two ERs are surprisingly quiet, possibly due to the cultural aspect and new refurbishment done in 2017 considering the work pattern. The nurse station is rated worst both in the questionnaire and objective measurement, which need an urgent improvement. The reverberation times in all the rooms are lower than 0.6 s, which complies with the latest Danish building regulation.

Acknowledgments

The authors are grateful to Prof. Seung-Ha Oh, the chairman of department of Otorhinolaryngology, SNUH, for arranging the measurement at the hospital and Mr. Jae-Gab Seo at KRISS and Dr. Sang-Yeob Lee at SNUH for their assistance with the measurements. A big thanks goes to Prof. Jeong-Guon Ih and Mr. In-Jee Jung at KAIST for lending/preparing the equipment and further fruitful comments. We also thank Dr. Woo-Keun Song and Mr. Moon-Ju Hwang at B&K for their help with the measurement equipment. The comments from Dr. Pyoung-Jik Lee from University of Liverpool on the questionnaire are also appreciated. The first author also thanks Danish Sound Innovation Network for its generous funding for the measurement trip to Korea.

Table 1. Summary of the noise level in SUNH.

Room	Index	Measurement duration (hours)	L_{Aeq} (dBA)	Remark
ER - Triage	1	22	55.6	-
	2	21	55.7	
	3	22	55.6	
ER - Treatment	1	22	54.5	-
	2	21	53.9	
	3	22	52.4	
ICU	1	22	65.7	Critical patient
	2	15	56.2	
Operating room	1	2	59	Small drill and suction
	2	2	62	Drill and Suction
	3	22	57	Suction
	4	0.1	49	Background noise
Examination room	1	2	55-65	-
Nurse station	1	0.5	58.0	Nurse station near patient ward
	2	0.5	64.1	Reception area in nurse station
	3	0.3	61.5	Preparation room
	4	0.1	62.4	Prep room, Sterilizer on
	5	0.5	61.5	Open waiting room, Children hospital
	6	0.2	62.2	Open waiting room, Children hospital 2
Reception	1	0.2	56.6	Reception, Otorhinolaryngology
	2	0.5	63.7	Reception, internal medicine
	3	0.2	62.2	Reception, children hospital
	4	0.2	67.0	Most crowded reception
Patient room	Single	0.3	37	Unoccupied, Door & window closed
	Single	0.3	50	Unoccupied, Window open/door closed
	Multiple	0.2	47	Occupied, Door open/window closed

Table 2. Summary of the reverberation time in SNUH

Room	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Operating room, EDT	0.48	0.58	0.53	0.56	0.55	0.44
Examination room, T_{20}	0.50	0.43	0.40	0.37	0.32	0.29
Patient room – Single, T_{20}	0.40	0.33	0.31	0.33	0.30	0.25

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