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NOTES

A Study in Hospital Noise—A Case From Taiwan

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Hospitals are places that allow patients to rest and recover, and therefore must be quiet inside and in the surrounding neighborhood. One medical center was chosen as a sample hospital. This hospital was a tertiary care center during the 2003 outbreak of the severe acute respiratory syndrome (SARS) in Taiwan. The measurement results show that the noise level in the wards and stations was between 50.3 and 68.1 dB which exceeded the suggested hospital ward sound level. The quietest units were the Surgical Intensive Care Unit and recovery rooms with a noise level lower than 50 dB during the night. The higher noise levels were in the hall and pharmacy which were highly populated areas. This study analyzed the causes of this excessive noise and used noise reduction methods. The paired t *test was performed and the results showed improvement methods were successful. This study found the noise levels reached 98.5–107.5 dB in power generator rooms and air-conditioning facilities, and suggests employees use ear plugs.*

noise hospital decibel (dB) patients hospital management SARS

1. INTRODUCTION

Hospitals are places that allow patients to rest and recover, and therefore must be quiet inside and in the surrounding neighborhood. Not only can noise cause temporary and permanent hearing loss, it can also harm the endocrine, digestive, and cardiovascular systems (Figure 1) [1, 2]. Noise can result in a decrease of worker productivity and an increase in human error [3]. Noise has also been found to negatively affect the quality of the patients' healing environment. Noise may elevate blood pressure, increase heart rate, stimulate the release of epinephrine (adrenaline), increase pain, and alter quality of sleep [4, 5, 6].

There are several standards used to regulate noise levels. For example, Occupational Safety and Health Administration (OSHA) [7] currently uses an 8-hr time weighted average (TWA) of 85 dB as the criterion for implementing an effective hearing conservation program [8]. Also, the Environmental Protection Agency [9] has established guidelines recommending noise levels not to exceed 45 dB in the daytime and 35 dB at night in hospitals. However, several studies indicate that noise levels in patients' rooms are much higher [4, 10, 11, 12, 13, 14].

Occasionally noise levels in the intensive care unit (ICU) reach as high as 100 [15] and 119.6 dB on orthopaedic wards [16]. Several studies show that, with proper methods, the hospital noise level could be controlled to 49.2~53.2 dB [17, 18].

Table 1 shows that most sound control standards are the same in the USA and Taiwan. The only two differences are (a) the USA set up a 1/2-hr limit, whereas Taiwan uses a 1/3-hr limit at 110 dBA, and (b) the USA set up 1/4-hr or lower limit, while Taiwan uses a 1/4-hr limit at 115 dBA.

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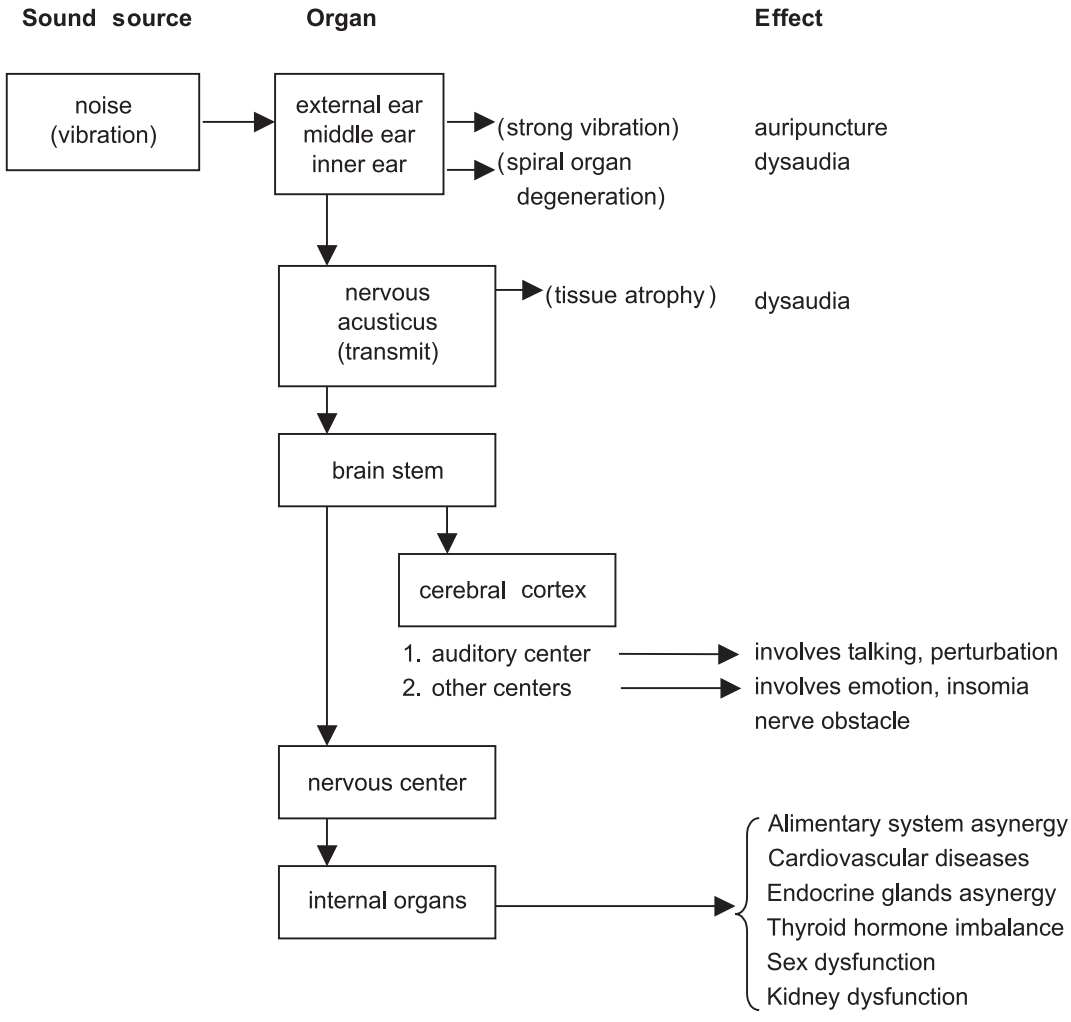

Figure 1. Effects noise has on humans.

TABLE 1. Sound Control Standards

Sound Level (dBA) Slow Response	Duration Per Day (hrs)	
	USA [7]	Taiwan [8]
90	8	8
92	6	6
95	4	4
97	3	3
100	2	2
105	1	1
110	1/2	1/3
115	≤1/4	1/4

Notes. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

As the reduction of emissions from machinery (noise, radiation, vibration, hazardous substances) has to be almost neglected [19], the purposes of this research include

- measuring and analyzing noise levels in the sample hospital;
- assessing hospital noise in light of accepted safety standards for workers and patients;
- developing methods to decrease noise exposure in the hospital environment;
- comparing noise levels before and after those methods have been implemented.

2. METHODS

2.1. Sampling

Chung-Shang University Medical Center is in the central Taiwanese city of Taichung. It is equipped with 1 300 general beds and 350 special beds. Chung Shan was the tertiary care center during the 2003 outbreak of the severe acute respiratory syndrome (SARS) in Taiwan and was responsible for treating SARS patients. The eighth- and ninth-floor wards were remodeled to accommodate suspected SARS patients. The emergency power generators were also strengthened to ensure that the whole system would not shut down in the case of a power outage. These five generators generated a total of 10 000 kV that produced a lot of noise that would be addressed later.

At Chung Shan, the large number of outpatients (4 500 patients/day) created high levels of noise because inpatients and outpatients had to compete for the use of the lab, X-ray, CT (computed tomography), pharmacy, and MRI (magnetic resonance imaging) equipment.

2.2. Measured Locations

We measured the noise levels in the general wards, ICUs, outpatient waiting areas, recovery rooms, pharmacy, hemodialysis center, laboratory, emergency department, and lobby. This study also measured areas less visited by patients such as parking lots and supply rooms, and areas restricted from patients and only for hospital workers such as emergency power generating facilities, air conditioning motors, and storage rooms.

2.3. Measuring Instrument

We used a sound level meter device (TES, Taiwan) corresponding with OSHA standards, and providing A- and C-weighted measurements. Measuring frequency: 31.5~8 000 Hz. Measuring height: 1.2 to 1.5 m (the same as the employees' and patients' working and treatment height).

2.4. Measurement Date and Time

This study measured the sound levels in the patients' area at three time periods during the day: in the morning (10 a.m.), in the afternoon (3 p.m.), and at night (8 p.m.). We measured the sound levels for the first time between May and July 2004, and for the second time from May to July 2005 after the improvement methods had been implemented.

3. RESULTS

Table 2 shows that the noise level in the wards and stations (5F–17F) was between 50.3 and 68.1 dB. The quietest units were the Surgical Intensive Care Unit (SICU) and the recovery rooms with a noise level lower than 50 dB during the night. The lower level can be attributed to the fact that visitors in those areas were prohibited from talking. Conversely, the highest noise levels were in the hall and pharmacy, which were highly populated areas.

Additional noise came from the five emergency power generators that served the ICUs, recovery rooms, operation rooms, and the high efficiency particulate air (HEPA) purifiers in the SARS wards (Table 3). Although the machines were located in another building, they caused a slight vibration in the ground that had to be factored into the noise level of populated hospital areas. The other noise factors listed in Table 3 were located in the same building as the generators. Their noise levels exceeded OSHA's 8-hr TWA limit of 85 dB, which was harmful for the hospital workers in those areas.

Our first measurement indicated that the emergency room, ICU, lobby, and pharmacy were too noisy. This study analyzed the causes of this excessive noise and recorded them on a fish bone chart (Figure 2). This study used the noise reduction methods listed in Table 5 in September 2004 [20]. Ten months later this study measured the noise levels a second time to see if there had been any improvement (Table 4).

TABLE 2. Hospital Sound Levels (dB) Before Improvements

Location	Morning	Afternoon	Night
17F wards	55.9	53.2	49.9
14F wards	52.9	53.4	50.5
10F wards	51.8	54.0	52.2
8F medical wards	49.7	52.4	51.7
7F medical wards	50.3	52.1	53.4
5F medical wards	51.0	52.1	50.8
Ward average	51.9	52.9	51.4
17F nursing station	57.1	56.9	48.3
14F nursing station	55.2	54.1	53.2
10F nursing station	54.8	55.2	52.0
8F nursing station	55.8	55.8	52.5
7F nursing station	54.8	55.7	54.3
5F nursing station	53.7	55.2	52.3
Nursing station average	55.2	55.5	52.1
MICU	57.8	57.1	54.8
Waiting rooms in internal medicine	60.3	61.3	52.8
Pharmacy 1[1]	66.0	67.9	57.5
Pharmacy 2[2]	65.9	69.2	58.2
Average	62.5	63.9	55.8
SICU	53.5	55.0	54.2
Hemodialysis center	57.6	57.5	Closed
Recovery rooms I[3]	54.3	54.9	52.8
Recovery rooms II[4]	54.0	53.6	53.0
Average	54.9	55.3	53.3
Outside emergency ward 1[5]	63.5	62.8	62.3
Outside emergency ward 2[6]	64.0	63.2	60.4
Inside emergency ward I[7]	57.9	57.5	52.2
Inside emergency ward II[8]	56.8	58.1	54.4
Average	60.6	60.4	57.3
2F waiting rooms	60.6	63.2	56.2
Laboratory	64.3	68.1	62.2
Hall (towards outside)	61.9	65.1	61.1
Hall (towards inside)	62.6	64.1	58.8
Average	62.4	65.1	59.6

Notes. MICU—Medical Intensive Care Unit, SICU—Surgical Intensive Care Unit; 1—pharmacy 1: near the exit, 2—pharmacy 2: center of pharmacy, 3—recovery rooms I: near the exit, 4—recovery rooms II: center of recovery rooms, 5—outside Emergency ward 1: near the outside door of emergency, 6—outside Emergency ward 2: center of emergency hall, 7—inside Emergency ward I: near the inside door of emergency, 8—inside Emergency ward II: center of emergency wards.

TABLE 3. Hospital Noise for Workers

Location	Sound level (dB)
B2 parking	64.5
B3 parking	65.9
5A mechanic room	76.7
3F central supply center	81.8
B2 emergency power generators	107.5
B3 air conditioning motors	103.4
1F storage room	98.5

In order to determine which noise improvement methods were effective, this study used a paired *t* test to compare the results (Table 6).

Table 6 shows that the noise level improved significantly in the morning and in the afternoon. It can be concluded that the improvement methods were successful and can be used by other facilities to regulate sound levels.

TABLE 4. Hospital Sound Levels (dB) After Improvements

Location	Morning	Afternoon	Night
17F wards	48.6	51.1	52.8
14F wards	52.5	54.3	50.5
10F wards	59.9	54.3	49.8
8F medical wards	51.5	52.1	50.3
7F medical wards	53.2	55.5	52.2
5F medical wards	50.9	50.5	50.5
Ward average	52.8	53.0	51.0
17F nursing station	55.3	55.9	52.0
14F nursing station	54.5	53.8	52.7
10F nursing station	53.0	53.5	52.7
8F nursing station	55.2	56.7	54.0
7F nursing station	52.2	52.5	52.5
5F nursing station	51.4	52.7	53.1
Nursing station average	53.6	54.1	52.8
MICU	54.7	51.7	55.3
Waiting rooms in internal medicine	57.2	54.4	52.8
Pharmacy 1[1]	51.7	59.9	56.6
Pharmacy 2[2]	65.1	63.1	61.9
Average	57.2	57.3	56.7
SICU	60.9	60.8	49.6
Hemodialysis center	54.1	55.1	Closed
Recovery rooms I[3]	52.4	54.3	49.0
Recovery rooms II[4]	53.4	53.5	50.1
Average	55.2	55.9	49.8
Outside emergency ward 1[5]	61.9	62.1	63.1
Outside emergency ward 2[6]	61.5	62.3	62.0
Inside emergency ward I[7]	53.7	52.3	55.8
Inside emergency ward II[8]	51.9	54.5	53.5
Average	57.3	57.8	58.6
2F waiting rooms	57.3	53.7	54.6
Laboratory	63.4	62.4	57.2
Hall (towards outside)	62.8	61.5	60.0
Hall (towards inside)	62.5	60.5	62.7
Average	61.5	59.5	58.6

Notes. MICU—Medical Intensive Care Unit, SICU—Surgical Intensive Care Unit; 1—pharmacy 1: near the exit, 2—pharmacy 2: center of pharmacy, 3—recovery rooms I: near the exit, 4—recovery rooms II: center of recovery rooms, 5—outside Emergency ward 1: near the outside door of emergency, 6—outside Emergency ward 2: center of emergency hall, 7—inside Emergency ward I: near the inside door of emergency, 8—inside Emergency ward II: center of emergency wards.

4. DISCUSSION

This study found the areas with the highest noise levels to be power generator rooms and air-conditioning facilities for workers. Employees should use ear plugs when working in those areas because noise levels reach 98.5–107.5 dB; such levels do not comply with OSHA's 8-hr exposure standards of safety and, if not properly adhered to, will cause hearing loss [21, 22, 23].

The noise reduction methods applied during this study proved to be successful and can be modeled by other medical facilities. Suggested methods include designing hospitals in a way that will reduce noise making factors, using low noise machines (e.g., quieter laundry machines), turning off ambulance sirens between 10 p.m. and 7 a.m., and modifying employee behavior and care procedures.

TABLE 5. Noise Reduction Methods

Noise Source	Reason for Noise	Noise Location	Improvement Method
Alerting bells, verbal calling of patients	Bells allow patients and family to call for assistance. The staff calls patients when it is their turn to receive care.	Medical wards ICU Hemodialysis center Recovery rooms Quarantine rooms	Demand quiet voices among outpatients. Request the staff to keep verbal calling at a minimum volume. Lower alerting bells' volume and increase flashing red lights.
Rowdy children	Children cause disturbance in the waiting rooms and wards.	Medical wards ICU	Request parents to keep their children under control. Increase the number of play rooms for children to contain the noise. Make posters that list noise regulation rules.
Rattling treatment cars	Treatment carts make too much noise when wheeled from place to place.	Medical wards	Improve treatment carts' tires and make the ground level. Place soft mats on hall floors.
Telephone ring	Telephones ring for a long time before being answered.	Nursing stations Outpatient departments	Adjust telephone ring volume to the lowest setting. Move telephones, so they can be answered faster.
Breaking ice	Hospital staff prepares ice for patient use.	MICU Waiting rooms	Prepare ice in enclosed staff areas only. Provide patients with ear plugs.
Air conditioning	The fans from the central air conditioning produce extra noise.	Wards	Lower the fan speed.
Physical therapy machines	The machines vibrate excessively.	Surgery wards	Increase insulation equipment in the machinery. Use machines in enclosed areas only.
Conversation of patients and visitors	Patients and their visitors talk too loudly in the ward and halls.	Emergency department	Limit the number of visitors in the ward Make extra visitors stay in waiting rooms. Increase waiting room space. Make posters that request quiet conversation.
Nurse activity	Careless nurses make excess noise while conducting business.	NICU	Modifications of nurses' behavior and care procedures. Closing infant incubator doors gently.
Mechanical ventilators	Extra noise is emitted from the tube bubble.	NICU	Fix and move the pressure bottle outside the infant incubator.

Notes. ICU—intensive care unit, MICU—Medical Intensive Care Unit, NICU—Neonatal Intensive Care Unit.

TABLE 6. Paired *t* Test of Before and After Noise Improvements

Noise Measurement Time	Paired Differences				*t* Value	*df*	Significance (two-tailed)
			95% CI of the Difference				
	M	*SD*	Lower	Upper			
Pair 1 Morning	–1.575	0.6100	–3.080	–0.074	-2.461	27	.04*
Pair 2 Afternoon	–2.275	0.6337	–3.575	–0.975	-3.590	27	.001**
Pair 3 Night	–0.174	0.4731	–1.146	0.798	-0.368	26	.716

Notes. *$p < .05$, **$p < .01$; CI—confidence interval.

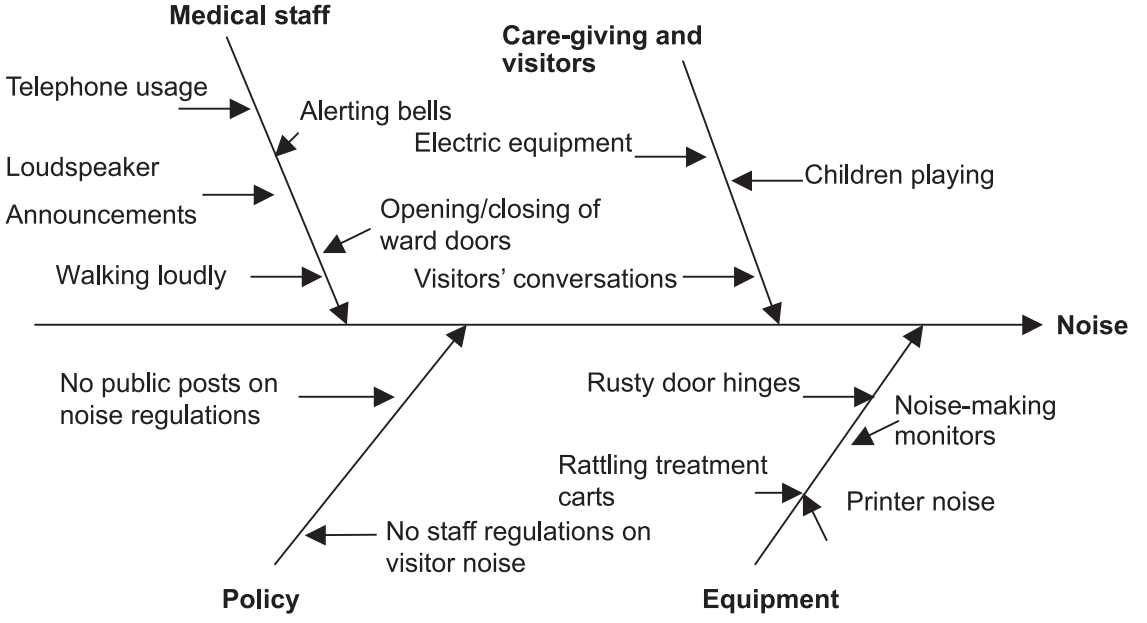

Figure 2. Fish bone chart of hospital noise sources.

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