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Rasmussen, Birgit; Carrascal García, Teresa; Secchi, Simone

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Acoustic regulations for hospital bedrooms – Comparison between selected countries in Europe

Birgit Rasmussen ¹

BUILD, Department of the Built Environment, Aalborg University, Denmark
A.C. Meyers Vænge 15, 2450 Copenhagen, Denmark

Teresa Carrascal García ²

Eduardo Torroja Institute for Construction Science
Serrano Galvache 4, 28033 Madrid, Spain

Simone Secchi ³

Department of Architecture, University of Florence
Via San Niccolò 93, 50125, Firenze, Italy

ABSTRACT

Regulatory acoustic requirements for hospitals exist in several countries in Europe, but many countries have either no or few regulatory limits or only recommendations. The purpose of limit values is to ensure optimal acoustic conditions for the patients under treatment and for the personnel for the various tasks taking place in many different rooms, e.g. bedrooms, examination and treatment rooms, corridors, stairwells, waiting and reception areas, canteens, offices, all with different acoustic needs. In addition, some rooms require special considerations like psychiatric rooms and noisy MR-scanning rooms. The extent of limit values varies considerably between countries. Some specify few, others several criteria. The findings from a comparative study carried out in selected countries in various geographical parts of Europe show a diversity of acoustic descriptors and limit values. As examples, this paper includes for hospital bedrooms criteria for reverberation time, airborne and impact sound insulation, noise from traffic and from service equipment. The discrepancies between countries are discussed, aiming at potential learning and implementation of improved limits. In addition to regulations or guidelines, some countries have hospitals included in national acoustic classification schemes with different acoustic quality levels. Indications of such class criteria are included in the paper.

1. INTRODUCTION

Acoustic conditions in hospitals are important for patients under treatment as well as for the staff. In hospitals, there is a variety of rooms with different acoustic needs, and acoustic regulations and/or acoustic quality classes or other guidelines exist in several countries, but are missing in other countries. Good acoustic conditions are important for patients' sleep and recovery as well as for the personnel's work conditions, thus reducing mistakes. For all, including visitors, good acoustic conditions help supporting a relaxed atmosphere and comfort. The purpose of this paper is to compare acoustic requirements for hospitals in selected countries in Europe, aiming at potential learning between countries

¹ bira@build.aau.dk

² tcarrascal@ietcc.csic.es

³ simone.secchi@unifi.it

and improving regulations. The selected countries and related regulations are Denmark [1], England [2], France [3], Italy [4]-[5], Norway [6], Portugal [7], Spain [8], Turkey [9]. This paper deals with hospital bedrooms and is a follow-up on previous studies about hospitals, such as reverberation time regulations for corridors and stairwells in hospitals [10], acoustic regulations and classes in the five Nordic countries for hospital bedrooms [11], and about acoustic regulations and case studies for hospitals in Italy [12].

2. PERFORMANCE AREAS IN ACOUSTIC REGULATIONS AND GUIDELINES

In most countries in Europe, acoustic regulations now exist for housing and schools and in several countries also for other building categories like e.g. hospitals. In addition and/or as an alternative, some countries also have guidelines or acoustic classification schemes. Acoustic regulations and classification criteria are typically about:

- Airborne sound insulation between rooms
- Impact sound insulation between rooms
- Facade sound insulation
- Service equipment noise
- Reverberation time or sound absorption

Building acoustic criteria are specified by a descriptor, a limit value, reference to a standard and sometimes to specific conditions, e.g. frequency range and/or test conditions. In Europe, most countries refer to ISO field measurement and rating standards, typically [13], [14], [15], [16], [17], [18], [19], [20]. Traffic noise may be determined according to [21]. At the design stage, the acoustic performance can be estimated using prediction methods, e.g. [22] and [23], with relevant acoustic input data.

Although many different acoustic limit values are needed for the variety of rooms in hospital buildings, it was decided to compare regulations for hospital bedrooms, which is a basic room type in hospitals and considered useful as a starting point for further comparisons. This paper focuses on such hospital bedrooms, and Figure 1 illustrates the acoustic requirements analysed in this paper for the selected countries.

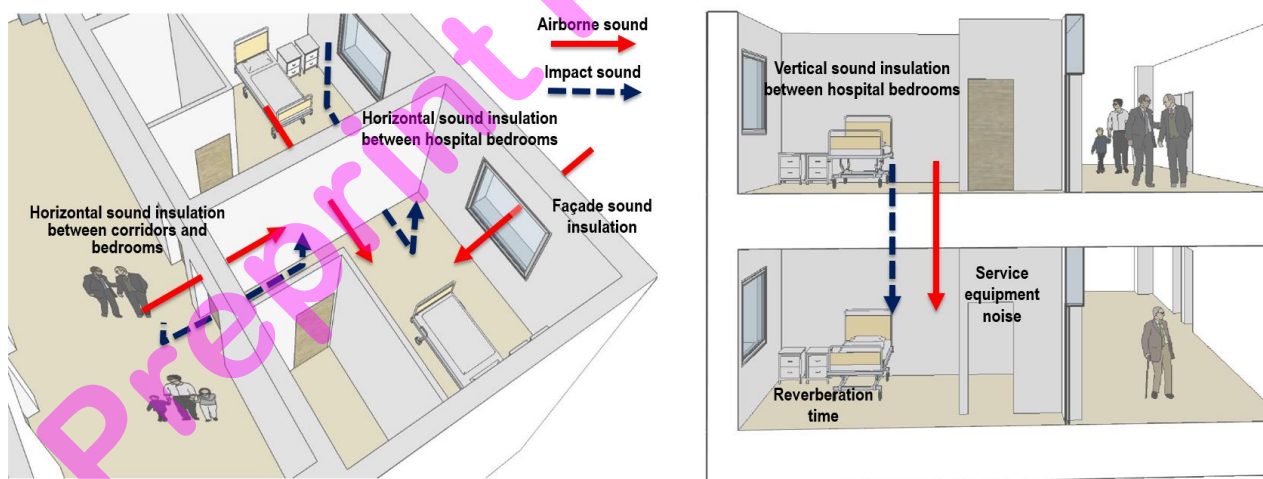


Figure 1 – Acoustic requirements for hospital bedrooms analysed for selected countries in Europe.

3. CHOOSING COUNTRIES FOR THE COMPARATIVE STUDY

When choosing countries for the study, it was decided to get various geographical parts of Europe presented, taking into account also the authors' language skills. The countries selected are the same as those chosen for reverberation time requirements for hospital corridors and stairwells [10], except that Belgium is not included now, since the authors decided to consider only countries with completed, published regulations or guidelines, thus omitting drafts. For Italy, we have split up into public and private hospitals, since regulations became different after the publication of the 2017 decree [5]. In Table 1, the countries are listed in alphabetical order.

Table 1 – Acoustic regulations for HOSPITALS – Overview countries selected for a comparative study in Europe.

Acoustic regulations for HOSPITALS – Overview countries selected for a comparative study in Europe – Febr. 2021				
Country	BR	ACS	ACS quality classes*	Comments on acoustic classes and relation to building regulations
Denmark	[1]	N/A	N/A	
England	[2]	N/A	N/A	
France	[3]	N/A	N/A	
Italy (public)	[4]-[5]	[24]	Superior and basic	For public hospitals, sound insulation regulations are found in [4] and [5] and described in [24], annexes A (superior class) and B (good performance), being mandatory for public hospitals.
Italy (private)	[4]	[24]	Superior and basic	For private hospitals, limit values are found in [4]. The Acoustic Classification Scheme [24] (superior and basic class) is voluntary for private hospitals.
Norway	[6]	[25]	A, B, C, D	For acoustic regulations, BR [6] refers to ACS [25], Class C, as mandatory minimum performance.
Portugal	[7]	N/A	N/A	
Spain	[8]	N/A	N/A	
Turkey	[9]	[9]	A, B, C, D, E, F	For acoustic regulations, BR [9] refers to ACS [9], Class C, as mandatory minimum performance.

BR = Building Regulations (regulatory requirements); ACS = Acoustic Classification Scheme; * Upper class first.
Note: Even in case of the same class denotation, descriptors and limit values vary between countries.

From Table 1, it appears that two of the selected countries (NO, TR) refer to Class C in the national acoustic classification scheme as the acoustic regulations. This way makes it quite easy to get an overview of the acoustic requirements for hospitals, since all limit values – including those presented in Tables 2-6 – are found in Class C in the classification documents [25] and [9], respectively. In general, regulations are mandatory and acoustic classification voluntary, unless referred to in the regulations. Examples of class limits are indicated in Section 4 below for sound insulation between hospital bedrooms according to the Norwegian standard [25].

4. ACOUSTIC CRITERIA FOR HOSPITALS

In the below Tables 2-6 are found acoustic regulations for normal hospital bedrooms in the selected countries. The limit values concern airborne and impact sound insulation (Tables 2-3), façade sound insulation (Table 4), service equipment noise (Table 5) and reverberation time (Table 6). For further details, see explanations in the tables and the references.

As seen in Tables 2 and 3, most of the selected countries have sound insulation requirements or recommendations for hospital bedrooms, but two countries (England and Italy) do not have limits for horizontal impact sound insulation. Comparisons of limit values show differences more than 10 dB between countries. Of the limits shown in Tables 2-3, Turkey is the country with the strictest requirements for horizontal airborne and impact sound insulation. For vertical sound insulation, slightly stricter values apply for public hospitals in Italy than for Turkey.

Examples of classification limits for sound insulation between hospital bedrooms in Norway [25] are the following for classes A-D (in descending order):

- Airborne: $R'_w \geq 52, 52, 48, 44$ dB (note that class A and B limits are the same)
- Impact: $L'_{n,w} \leq 53, 55, 58, 63$ dB.

The standard [25] includes class criteria for all building categories, including e.g. dwellings, schools, kindergarten, healthcare buildings, and offices in separate chapters. The building regulations [6] refer to Class C for information about the mandatory minimum performance.

Table 2 – Acoustic regulations for HOSPITAL bedrooms – Airborne sound insulation.

Acoustic regulations for HOSPITAL bedrooms ⁽¹⁾ – Airborne sound insulation – Febr. 2021					
Country	BR	Rooms ⁽³⁾	Requirement [dB] ⁽²⁾		Comments
			Horizontal	Vertical	
Denmark	[1]	Between bedrooms Corridor to bedroom	$(R'_w \geq 48)^{(2)}$ $(R'_w \geq 35)^{(2)}$	$(R'_w \geq 51)^{(2)}$	
England	[2]	Between bedrooms Corridor to bedroom	$(D_{nT,w} \geq 42)^{(2)}$ $(R_w \geq 30-35 \text{ dB})^{(2)}$	$(D_{nT,w} \geq 42)^{(2)}$	Values for single bedrooms. Requirements for other bedrooms are found in [2], e.g. bedrooms for children. Recommendations for door sets.
France	[3]	Between bedrooms Corridor to bedroom	$D_{nT,w} + C \geq 42$ $D_{nT,w} + C \geq 27$	$D_{nT,w} \geq 42$	
Italy (public)	[4]-[5]	Between bedrooms Corridor to bedroom	$D_{nT,w} \geq 50$ $D_{nT,w} \geq 30$	$D_{nT,w} \geq 55$	BR [5] refers to superior class of annex A in ACS [24]. BR [5] refers to good performance of annex B in ACS [24].
Italy (private)	[4]	Between bedrooms Corridor to bedroom	None	None	No regulations for private hospitals, but criteria from ACS [24] may be applied voluntarily.
Norway	[6]	Between bedrooms Corridor to bedroom	$R'_w \geq 48$ $R'_w \geq 34$	$R'_w \geq 48$	BR [6] refers to Class C in ACS [25].
Portugal	[7]	Between bedrooms Corridor to bedroom	$D_{nT,w} \geq 45$ $D_{nT,w} \geq 30$	$D_{nT,w} \geq 45$	
Spain	[8]	Between bedrooms Corridor to bedroom	$D_{nT,w} + C_{100-5000} \geq 50$ $R_A \geq 50 - 30$	$D_{nT,w} + C_{100-5000} \geq 50$	Horizontal: For walls containing doors leading to corridors. $R_A \approx R_w + C_{100-5000} \geq 50$ for the wall, and ≥ 30 for the door set.
Turkey	[9]	Between bedrooms Corridor to bedroom	$D_{nT,w} + C \geq 52$ $D_{nT,w} + C \geq 38$	$D_{nT,w} + C \geq 52$	BR [9] refers to Class C in ACS [9].

(1) Overview information only. Detailed criteria and conditions are found in references.
 (2) Limits in (brackets) = Recommendation.
 (3) Corridor means there is a door between the hospital bedroom and the corridor. If there is no door, stricter limits may apply.

Table 3 – Acoustic regulations for HOSPITAL bedrooms – Impact sound insulation.

Acoustic regulations for HOSPITAL bedrooms ⁽¹⁾ – Impact sound insulation – Febr. 2021					
Country	BR	Rooms	Requirement [dB] ⁽²⁾		Comments
			Horizontal	Vertical	
Denmark	[1]	Between bedrooms Corridor to bedroom	$(L'_{n,w} \leq 58)^{(2)}$ $(L'_{n,w} \leq 58)^{(2)}$	$(L'_{n,w} \leq 58)^{(2)}$ $(L'_{n,w} \leq 58)^{(2)}$	
England	[2]	Between bedrooms Corridor to bedroom	None	$(L'_{nT,w} \leq 65)^{(2)}$	
France	[3]	Between bedrooms Corridor to bedroom	$L'_{nT,w} \leq 60$	$L'_{nT,w} \leq 60$	
Italy (public)	[4]-[5]	Between bedrooms Corridor to bedroom	None	$L'_{n,w} \leq 53$ $L'_{n,w} \leq 53$	BR [5] refers to superior class of annex A in ACS [24].
Italy (private)	[4]	Between bedrooms Corridor to bedroom	None	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	For private hospitals, limit values are given in the Decree 5/12/1997 [4].
Norway	[6]	Between bedrooms Corridor to bedroom	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 58$	BR [6] refers to Class C in ACS [25].
Portugal	[7]	Between bedrooms Corridor to bedroom	$L'_{n,w} \leq 65$	$L'_{n,w} \leq 65$	
Spain	[8]	Between bedrooms Corridor to bedroom	$L'_{nT,w} \leq 65$	$L'_{nT,w} \leq 65$	
Turkey	[9]	Between bedrooms Corridor to bedroom	$L'_{nT,w} \leq 54$ $L'_{nT,w} \leq 54$	$L'_{nT,w} \leq 54$	BR [9] refers to Class C in ACS [9].

(1) Overview information only. Detailed criteria and conditions are found in references.
 (2) Limits in (brackets) = Recommendation.

Table 4 shows façade sound insulation required for hospital bedrooms. While Italy has facade sound insulation limits independent from the outdoor noise, all other countries have increasing limits with increasing outdoor traffic noise levels. In Denmark, England, Norway and Turkey, the requirements are expressed directly as A-weighted equivalent indoor sound pressure levels, implying stricter sound insulation limits for higher traffic noise levels. France, Portugal and Spain express their requirements as façade sound insulation with limits depending on the outdoor noise levels (corresponding to a table). For further details, see Table 4 and the references.

Table 4 – Acoustic regulations for HOSPITAL bedrooms – Facade sound insulation.

Acoustic regulations for HOSPITAL bedrooms ⁽¹⁾ – Road traffic noise – Febr. 2021				
Country	BR	Requirement [dB] ⁽²⁾	Furnished	Comments
Denmark	[1]	$(L_{den} \text{ (indoor)})^{(3)} \leq 33$ ⁽²⁾	+	
England	[2]	$(L_{Aeq,1hr} \text{ daytime} \leq 40)$ ⁽²⁾ $(L_{Aeq,1hr} \text{ night} \leq 35)$ ⁽²⁾ $(L_{Amax,t} \text{ night} \leq 45)$ ⁽²⁾	+	Limits for single bedrooms. Limits increase 5 dB for multi-bed rooms.
France	[3]	$D_{nT,A,tr}^{(4)} \geq 30$	N/A	Required $D_{nT,A,tr}$ varies from 30 to 45 dB, depending on the type of road and its distance to the façade. Requirement corrected depending on the existence of noise barriers.
Italy (public)	[4]-[5]	$D_{2m,nT,w} \geq 45$ ⁽⁴⁾	N/A	Fixed façade sound insulation limit independent of the outdoor SPL.
Italy (private)	[4]	$D_{2m,nT,w} \geq 45$ ⁽⁴⁾	N/A	Fixed façade sound insulation limit independent of the outdoor SPL.
Norway	[6]	$L_{p,A,24h} \text{ (indoor)} \leq 30$ $L_{p,AF,max, 23-07} \text{ (indoor)} \leq 45$	+	BR [6] refers to Class C in ACS [25].
Portugal	[7]	$D_{2m,nT,w} \geq 28$	N/A	$D_{2m,nT,w} \geq 28$ or ≥ 33 depending on the type of area the building is located [26]
Spain	[8]	$D_{2m,nT,A,tr} \approx D_{2m,nT} + C_{tr} \geq 30$	N/A	Valid for $L_{day} \leq 60$ dB. For $L_{day} \leq 65, \leq 70, \leq 75$ or > 75 dB, limits 32, 37, 42, 47 dB apply.
Turkey	[9]	$L_{A,eq} \text{ (indoor)} \leq 34$	+	BR [9] refers to Class C in ACS [9]. Day-evening-night period applied.

(1) Overview information only. Detailed criteria and conditions are found in the references.
 (2) Limits in (brackets) = Recommendation.
 (3) DK: Day 07-19 (default), Evening 19-22, Night 22-07. L_{den} is defined in END (2002).
 The Danish Building Code refers to L_{den} as the only limit and valid for roads and railways separately.
 (4) The superior limit given by the Decree 11 October 2017 [24] (public hospitals) is lower than that given by the decree 5 December 1997 [5]. Therefore, the same limit applies both to public and private hospitals.

Limit values for service equipment noise are found in Table 5. Measurement methods are found in the building regulations. It is seen that different descriptors are applied, which make comparisons more complicated. In general, all countries rely on a descriptor based in L_{Aeq} , A-weighted equivalent sound pressure level. The standards referred to are basically either ISO 10052 [15] or ISO 16032 [16], but then additional methods apply for low-frequency noise and correction for pure tones, impulses and intermittent noise. Some countries apply different limits and procedures for continuous sources, e.g. ventilation systems, and other sources with changing noise emission during the operating cycle.

Table 5 – Acoustic regulations for HOSPITAL bedrooms – Service equipment noise.

Acoustic regulations for HOSPITAL bedrooms ⁽¹⁾ – Service equipment noise – Febr. 2021				
Country	BR	Requirement [dB] ⁽²⁾	Furnished	Comments
Denmark	[1]	$(L_{A,eq} \leq 30)$ ⁽²⁾	+	
England	[2]	$(NR \leq 30)$ ⁽²⁾	+	
France	[3]	$L_{nAT} \leq 30$ $L_{nAT} \leq 35$	Not specified	Noise produced by communal equipment or individual equipment inside the room Noise produced by plumbing and drainage systems in adjacent rooms
Italy (public)	[4]-[5]	$L_{ic} \leq 28$ ⁽³⁾ $L_{id} \leq 34$ ⁽³⁾	+	Equivalent SPL from service equipment with continuous operation Maximum SPL from service equipment with discontinuous operation
Italy (private)	[4]	$L_{Aeq} \leq 25$ $L_{ASmax} \leq 35$	Not specified	Equivalent SPL from service equipment with continuous operation Maximum SPL from service equipment with discontinuous operation
Norway	[6]	$L_{p,A,T} \leq 28$ $L_{p,AF,max} \leq 30$	+	BR [6] refers to Class C in ACS [25].
Portugal	[7]	$L_{Ar,nT} \leq 35$ $L_{Ar,nT} \leq 30$	Not specified	For building services producing a continuous noise For building services producing intermittent noises $L_{Ar,nT} = L_{A,eq} + \text{corrections for background noise, tonal, and impulsive noise}$
Spain	[8],[28]	$L_{k,d}; L_{k,e} \leq 35$ $L_{k,n} \leq 25$	Not specified	Limit value $L_k = L_{A,eq,T} + \text{corrections for background noise, tonal, impulsive and LF noise}$
Turkey	[9]	$L_{A,eq} \leq 30$ $L_{AF,max,nT} \leq 34$	+	BR [9] refers to Class C in ACS [9]. – The two limits are for continuous and intermittent noise, respectively.

(1) Overview information only. Detailed criteria and conditions are found in references.
 (2) Limits in (brackets) = Recommendation.
 (3) The descriptors are explained in [12] and [24].

Table 6 shows reverberation time requirements for hospital bedrooms. Of eight countries, five have limits for T, but with different frequency ranges, one has a limit for sound absorption instead and two countries (Italy and Spain) have no limits.

Table 6 – Acoustic regulations for HOSPITAL bedrooms – Reverberation time.

Acoustic regulations for HOSPITAL bedrooms ⁽¹⁾ – Reverberation time – Febr. 2021					
Country	BR	Requirement [dB] ⁽²⁾	Furnished	Freq. range [Hz]	Comments
Denmark	[1]	$(T \leq 0.6)$ ⁽²⁾	+	125-4000 ⁽³⁾	
England	[2]	See comment	N/A	250-4000	No T limit, but a minimum absorption area equivalent to a class C absorber, EN ISO 11654 [20]), for 80% of the floor area is recommended.
France	[3]	$T_r \leq 0.8$ ⁽⁴⁾	+	500-2000 ⁽⁴⁾	Volume $\leq 250\text{m}^3$. A typical bedroom for two beds is estimated to $< 60\text{m}^3$. For rooms with a bigger volume, see reference [3].
Italy (public)	[4]-[5]	None ⁽⁵⁾	N/A	N/A	Currently, no limit values ⁽⁵⁾ .
Italy (private)	[4]	None	N/A	N/A	No limits values
Norway	[6]	$T \leq 0.6$ ⁽³⁾	+	125-4000 ⁽³⁾	BR [6] refers to Class C in ACS [25].
Portugal	[7]	$T \leq 0.15 \cdot V^{1/3}$	+	500-2000 ⁽⁴⁾	Limits for multi-bed rooms. Volume $\geq 100\text{m}^3$
Spain	[8]	None	N/A	N/A	
Turkey	[9]	$T \leq 0.5$	+	250-2000 ⁽⁴⁾	BR [9] refers to Class C in ACS [9].

(1) Overview information only. Detailed criteria and conditions are found in references.
 (2) Limits in (brackets) = Recommendation
 (3) Denmark: Max. in each 1/1 oct. band. For 125Hz, +20% accepted; Norway: Max. in each 1/1 oct. band. For 125Hz, +40% accepted. For 250-4000 Hz, deviations up to +20 % accepted, if the mean value for those frequencies does not exceed the limit value.
 (4) T is defined as the average for the frequency bands indicated.
 (5) Public hospital bedrooms must fulfil requirements in UNI 11532-1 [27], but currently, the part dealing with hospitals has not been completed.

5. SUMMARY AND CONCLUSIONS

Acoustic regulations for hospitals aim at on one hand providing comfort and wellbeing for the patients, which is essential for recovery, and on the other hand providing good work conditions for the staff. For these reasons various limits about airborne and impact sound insulation, indoor traffic noise, service equipment noise and reverberation time are relevant and exist in national regulations or recommendations in several countries. Since it is known from comparative studies of housing, schools and offices, cf. e.g. [29], [30], [31], [32], [33], that acoustic requirements vary considerably between countries, it was found relevant to compare acoustic limit values for hospitals also, again aiming at mutual learning between countries.

Limit values depend on the room types. As a first step to know more about hospitals, it was decided to compare acoustic limit values for hospital bedrooms in eight countries in Europe. For all types of limits, both descriptors and limit values vary between countries. For airborne and impact sound insulation, differences between countries are more than 10 dB, and for two countries there are no requirements for horizontal impact sound insulation. For traffic noise and service equipment noise, a detailed comparison would require a much more detailed study of national guidelines. However, what is interesting is that some countries have different limit values for continuous sources (like e.g. ventilation noise) and discontinuous sources (like e.g. flushing water). For reverberation time, both frequency ranges and limit values vary, but what is especially important to notice is that two countries do not have any requirements for hospital bedrooms, although the comfort for patients and staff – including communication – is highly dependent on the reverberation.

The findings from the current study of hospital bedrooms show that exchange of experiences between countries would be useful, aiming at improving and optimizing acoustic requirements for hospitals. It is recommended and intended to continue comparative studies of more hospital room types to get a wider view on which requirements are appropriate for other important facilities in hospitals.

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